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Report of

**SIXTH
NATIONAL
CONFERENCE
ON WHEAT
UTILIZATION
RESEARCH**

OAKLAND, CALIFORNIA
November 5-7, 1969

**Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE**

THE SIXTH NATIONAL CONFERENCE ON WHEAT UTILIZATION RESEARCH was held in Oakland, Calif. , November 5-7, 1969. Director A. I. Morgan, Jr. , of the Western Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture, Albany, Calif. , welcomed the attendants.

The objective of the wheat utilization research conference is to provide a means for reviewing the current status of research on wheat utilization and an opportunity to exchange information and ideas and discuss problems of all segments of the wheat industry, all to further progress in increasing the use of wheat.

Sponsors of the Conference were Agricultural Research Service, U. S. Department of Agriculture; Great Plains Wheat, Inc. , and affiliated State agencies; Millers' National Federation; National Association of Wheat Growers; and Western Wheat Associates, U. S. A. , Inc. , and affiliated State agencies. Chairman of the Program Committee and Local Arrangements Committee was Assistant Director J. W. Pence, WURDD, ARS, USDA.

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This report was prepared at the Western Regional Research Laboratory, Albany, Calif. 94710--headquarters of the Western Utilization Research and Development Division, ARS, USDA. Copies are available upon request.

CONTENTS

Industrial Adoptions and Accomplishments, R. J. Dimler - - - - -	1
Food and Feed Adoptions and Accomplishments, A. I. Morgan, Jr. and D. A. Fellers - - - - -	7
Industrial Alcohol from Wheat, Dwight L. Miller - - - - -	20
Pulp and Paper from Wheat Straw, Dwight L. Miller - - - - -	34
Carrying Capacity of U.S. Wheats for European Wheats, D. K. Mecham - - - - -	39
Suppression of Excess Alpha-Amylase in Sprout-Damaged Wheats, Maura M. Bean and J. Garrin Fullington - - - - -	49
High Protein Breads, W. J. Hoover - - - - -	61
Reaction of Stored-Product Insects to Some Newly Developed Whole Wheat Products, Hobart P. Boles and Ralph L. Ernst - - - - -	67
Effect of Salts on Insect Resistance of Cereal Products, Athia Bano - - - - -	74
San Francisco Sour French Bread Nowhere Else, Why?, T. Frank Sugihara - - - - -	85
Dry Air Expansion to Improve Grains for Feed, Howard G. Walker, Jr. - - - - -	93
Biological Availability of Nutrients and Computer Evaluation of Millfeeds, G. O. Kohler, R. M. Saunders, D. D. Kuzmicky, and R. V. Enochian - - - - -	102
Pollution-Free Separation of Starch and Flour Proteins, D. A. Fellers and P. H. Johnston - - - - -	114
Starch and Flour Products in Paper and Rubber, C. R. Russell - - - - -	122
Starch Products for Plastics and Flocculants, C. E. Rist - - - - -	137
Prospects for Nonfood Uses of Gluten, G. E. Inglett - - - - -	144
Water Resistant Plywood Adhesive Based on Whole Wheat Flour, Mark F. Adams, R. A. V. Raff, and Helen F. Austin - - - - -	156
High Protein--Lysine Rich Wheats, P. J. Mattern, V. A. Johnson, and J. W. Schmidt - - - - -	161
High Yielding Wheats, the Milling and Baking Outlook, K. A. Gilles and W. C. Shuey - - - - -	172
Wheat Protein Concentrate in Baked Goods, K. Kulp - - - - -	183
What's Ahead for the Baking Industry? - Part I, J. A. Shellenberger - - - - -	189
What's Ahead for the Baking Industry? - Part II, James W. Pence - - - - -	191
Attendance List - - - - -	198

SIXTH NATIONAL CONFERENCE ON WHEAT UTILIZATION RESEARCH

INDUSTRIAL ADOPTIONS AND ACCOMPLISHMENTS

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Wheat is primarily a food grain. However, there are significant industrial uses of wheat products although the amounts involved may seem small alongside the wheat supply. In this discussion, I shall review the status of the industrial uses of wheat and give some indication how USDA utilization research has contributed to such uses. Also, I shall comment briefly on some problems relative to using wheat, in contrast to other cereal grains, as a raw material source for industry.

Industrial use has been strongly influenced by competition from other cereal grains, particularly corn and, to some extent, grain sorghum. One reason the grains are competitive is similarity in chemical composition. This similarity is brought out by the analytical data in table 1. In all major cereal grains,

Table 1.--Average percentage composition of common cereal grains^{1/}

Grain	Starch	Protein	Oil	Fiber	Minor constituents ^{2/}
Hard wheat	64	14	2	2	18
Soft wheat	69	10	2	2	17
Dent corn	72	10	5	2	11
Sorghum	71	13	3	2	11

^{1/} Moisture-free basis.

^{2/} Includes minerals, sugars, pentosans, and vitamins.

starch is the main constituent accounting for some 64 to 72 percent of their dry weight. Most industrial uses of cereal grains, therefore, are based on starch, either isolated as such or present as the main contributor to the properties of the flour. For many applications, but not all, the different cereal starches, along with potato and tapioca starches, are sufficiently alike in properties to be interchangeable. In such applications, factors other than the kind of starch or flour govern the choice.

Economics of the cereal grain supply and cost of processing generally control the initial choice of raw material in the industrial market. The impact of economics is illustrated, for example, by the estimated industrial use of cereal grains in 1963 (table 2)

Table 2.--Estimated industrial use of cereals, 1963

Type of cereal product	Million pounds ^{1/}
Wet-milled corn and sorghum products	2,060
Dry-milled corn and sorghum products	270 ^{2/}
Dry-milled wheat products	145
Wet-milled wheat products	60
Total	2,535

^{1/} Excludes fermentation uses.

^{2/} Estimate for 1964.

as given by Warren K. Trotter in his analysis of the "Economic Outlook for Increased Industrial Use of Cereals" presented at the meeting of the American Association of Cereal Chemists in 1965 (1).

Corn and grain sorghum generally have been lower priced than wheat and therefore became the favored raw materials for industrial use. Products from corn and sorghum accounted for about 90 percent of the cereal products used industrially in 1963 (table 2) while wheat accounted for just under 10 percent. Starch and starch derivatives, produced by the wet-milling industries, are the basis for most commercial uses. The products of wet-milling represented more than 80 percent of the total in 1963. Corn wet-milling plants are located mainly in the Corn Belt, near the source of supply.

Economics related to choice of raw material are influenced by the supply and consumer situation in two respects. One is the overall effect of supply on price of the grain; surpluses depress the price unless controls are put into effect. The other is the geographic relationship between where the grain is grown and processed and where the products are used. Savings in shipping costs of finished products to the user may justify in some regions the use of locally grown wheat rather than corn even though the farm price of wheat may be above that of corn.

While I have emphasized economics as a controlling factor in the choice of grain for production of starch or flour for industrial uses, a number of other things can influence the choice between wheat and other cereal grains. For example, once an industry is established on the basis of corn, a change to wheat becomes

unlikely despite the general interchangeability between corn starch and wheat starch in industrial markets. From the viewpoint of the user, the differences in properties of the starch usually are great enough to require some adjustments in operations which discourage temporary and frequent changeover from one kind of starch to another. For the manufacturer, the processes for producing the starch are not sufficiently alike to justify change of raw material unless a significant price differential not only exists, but can be expected to continue for a number of years. These deterrents to change must be recognized in considering the effect of the recent downward trend in wheat prices. This trend is encouraging the use of wheat as a feed grain. However, the lower price of wheat cannot be expected to have an immediate impact on the use of wheat industrially, in part because there is no assurance that prices will remain low for several years.

Still another factor in the competition between wheat and corn is related to the manufacture and sale of products that go into industrial use. Generally, established companies have both a research and a sales-service operation upon which their customers depend. This setup certainly is true of the large cornstarch industry. For example, paper and textile companies that are major users of starch depend on the starch companies not only to improve starch products through research, but also to provide sales-service assistance in overcoming difficulties that may be encountered during their use. Any new producer of cereal products for industrial use is likely to be at a disadvantage initially because he lacks a sales-service organization. Or to put it another way, anyone considering entry into the field of industrial cereal products must recognize the importance of the research and sales-service aspect to meet competition.

Finally, users of cereal products will generally favor the company assuring them of advantages of a continuous supply of products at stable prices. Such stability of price and supply depends on several factors, among which are a reasonable scale of production and sales, as well as a constant supply and price for raw materials. With that background, let us review the past and current situation.

At the Fourth National Conference on Wheat Utilization Research in 1965, Mr. D. L. Miller, Assistant Director of the Northern Regional Research Laboratory, discussed industrial uses of wheat and flour (2). Since then, he has updated the graph showing the variations over past years in the use of wheat in the United States for food, feed, and industrial uses. Figure 1 shows clearly the low proportion of wheat going into industrial uses during most of the period covered. The impact of World War II which disrupted the normal supply and demand situation is reflected by the increase in both industrial and feed use of wheat during

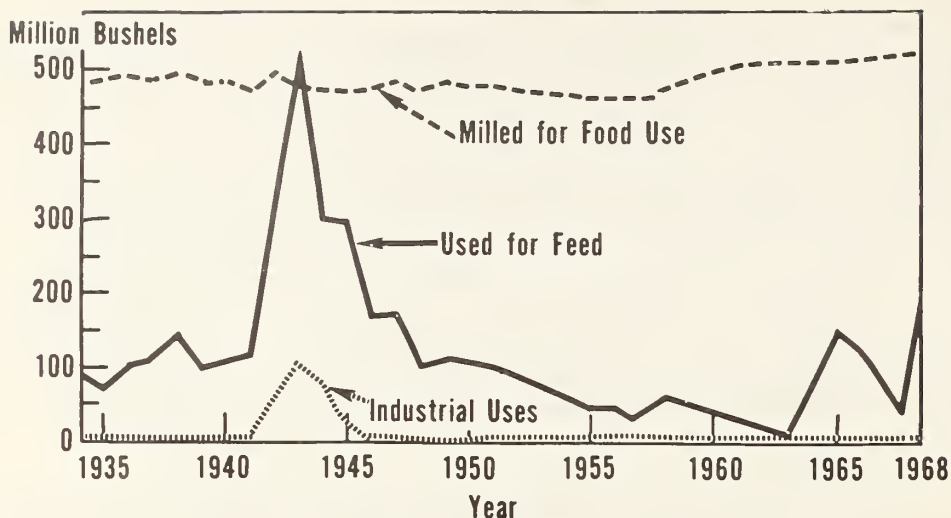


Figure 1.--Utilization of wheat in United States.

the period 1942-1945. Most of the increase in industrial use of wheat during the war period is accounted for by alcohol production. Research at the Northern Laboratory assisted in this substantial production of alcohol from wheat, as did the research efforts of a number of industrial corporations, commercial laboratories, universities, and other government agencies.

Also, during the war period the Northern Laboratory conducted research on wheat starch production by improved and modified procedures. At least one, the Batter Process (fig. 2), has been the basis for processes used today in the production of starch and wheat gluten protein by several mills. While the gluten goes primarily into food, much of the starch has industrial outlets.

The quantities of wheat used industrially are best expressed in terms of flour rather than grain since flour is the form in which the wheat is used as a raw material. The estimated amount of wheat flour finding industrial uses in 1968 is given in table 3. The values have been brought up-to-date by Mr. Miller from the estimates he presented in 1965 (2). Since no published values are available on sales for specific end uses, these estimates represent our best judgment based on numerous industrial contacts.

The industrial uses of wheat flour actually have been nearly stable. The changes since 1965 have included an increase in adhesives (from 125 to 130 million pounds) and in composition board (25 to 50 million pounds). Use of flour in production of starch and gluten was estimated to have decreased from 265 to 250 million pounds. During this period, at least one wheat starch producer decreased his operation considerably while one company started producing starch for the first time. Wheat starch is used in foods as well as industrially.

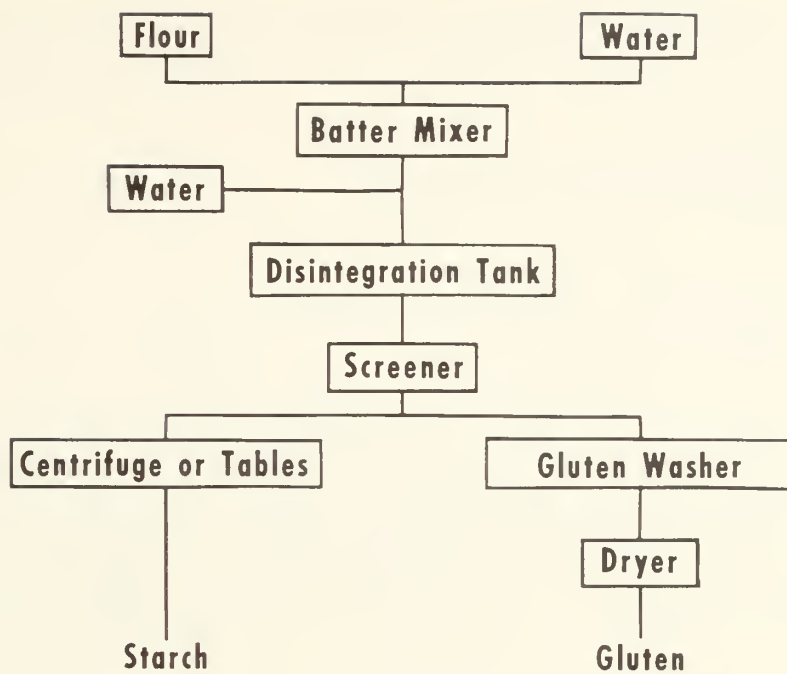


Figure 2.--Batter process flow sheet.

Table 3.--Estimated industrial uses of wheat flour
in 1965 and 1968

Use	Flour used, million pounds	
	1965	1968
Industrial alcohol	4	4
Plywood and laminating adhesives	125	130
Composition board	25	50
Starch and gluten	265	250
Miscellaneous	<u>1</u>	<u>1</u>
Total	420	435

In considering the commercial market for wheat flour, one must remember that the flour generally used is second clears rather than straight flour; therefore, these uses do not have so direct an impact on wheat utilization as might be expected. However, profitable disposition of the clears flour is essential to the economy and continued operation of the wheat milling industry. In turn, the farmer's market for his wheat largely depends on the success of the miller.

The estimated industrial uses of wheat starch in 1968 are shown in table 4, together with the estimate previously made (2) for 1965. The situation has changed more for starch than for flour since 1965. We believe that the major industrial increase for wheat starch has been in paper products for laminating and corrugating (from 24 to 30 million pounds) and the newly identified

Table 4.--Estimated industrial uses of wheat starch

Use	Starch used, million pounds	
	1965	1968
Laundries	13	12
Paper laminating and corrugating	24	30
Adhesives	10	10
Textiles	11	12
Wallpaper and billboard paste	20	20
Paper additives	--	35
Miscellaneous	2	4
Total	80	123

entry into paper additives to the extent of 35 million pounds. We are confident that research at the Northern Laboratory has contributed substantially to these increases although a quantitative relationship cannot be established. A decrease of 1 million pounds may have occurred in use in laundries, while textile use may have increased 1 million pounds and miscellaneous uses, 2 million pounds. Overall industrial market for wheat starch is believed to have increased from 80 to 123 million pounds. The estimated decrease in use of wheat flour for producing starch and gluten (table 3) thus would reflect a decrease in food uses of wheat starch.

From the standpoint of industrial adoptions and accomplishments, the most noteworthy development since our report in 1965 (2) is the entry of the Centennial Mills Division of VWR United Corporation into wheat starch production. According to our information, other producers of wheat starch and gluten in the United States are the Huron Milling Division of Hercules, Inc.; General Mills, Inc.; Loma Linda, Inc.; the Keever Starch Division of A. E. Staley Manufacturing Company; Midwest Solvents Company; Wheat Products Company; and Worthington Foods. While details of operations at Centennial Mills have not been published, we understand that the Batter Process worked out at the Northern Laboratory was used at least as a starting point for developing production methods.

The importance of several of the factors mentioned earlier relative to choice of raw material is well illustrated by the Centennial Mills operation. Its geographical location in the Pacific Northwest is advantageously close to paper mills, which constitute a logical outlet for much of the starch. The proximity to wheat supply and user outlets provides an advantage because shipping charges for Midwestern cornstarch would raise costs. At the same time, markets for undenatured gluten in food uses exist in the West. As part of a flour milling operation, the production of starch and gluten provides an attractive outlet within the company for second clears flour, without dependence on an external

source of supply. We understand that a further strength of this operation has been the rapid development of a good sales-service relationship with customers and the assurance of a stable price and supply of products. Obviously, this wheat starch production would not be so favorable if it were remote from consumers, such as the paper industry, or if it were in the same vicinity as a cornstarch producer so that shipping costs for wheat starch would not be lower than for cornstarch.

In summary, the industrial uses of wheat flour and starch have remained low but stable over the past 20 years or so. A general limitation has been the inability of wheat fractions to compete economically with similar products obtained from corn and sorghum. Once in awhile the specific properties of wheat products or the advantages of location have permitted successful entry into the industrial market. Research continues, of course, to seek products that will give wheat a distinct advantage. On the other hand, new applications for starch, such as those to be described in subsequent papers, are available to wheat whenever economics and processing facilities are favorable.

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1. Trotter, W. K. Cereal Sci. Today 11(2): 36-44, February 1966.
2. Miller, D. L. Fourth National Conference on Wheat Utilization Research, U.S. Dept. Agr. ARS 74-35, pp. 80-87, 1966.

FOOD AND FEED ADOPTIONS AND ACCOMPLISHMENTS

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The history of wheat, were such a text available, might well read like a travelogue through the kitchens and food factories of time and nations. Wheat has always been a food grain of man and today wheat is still nearly synonymous with food.

We are all readily familiar with our breads, cakes, cookies, doughnuts, pancakes, waffles, pies, spaghetti, rolls, macaroni, wheat flakes, farina, and other products. But there is a world

more of wheat food products. How many of you have eaten chapatties, cous cous, tandoori, instant raumen, udon, steamed bread, bulgur, wheat atolé, sangak, taftoon, barbari, lavash, uppuma, puris, kachauris, puratha, haliva, kesari, sewayan, or wheat tempeh? What gastronomic treats are we missing? Could there be application of these foods in our own country?

U.S. production of wheat for 1969 is projected at about 1,425 million bushels (1). Domestic wheat usage is projected at 805 million bushels and represents a little more than 56 percent of production.

Let's look at the domestic usage. Of the 805 million bushels, 525 million are projected for use as food, 225 million for feed, and 55 million for seed. I think you can see that wheat is first a food grain and second, if the price is right, a feed grain.

What about our export wheat?--almost exclusively for food uses.

Trends in Food and Feed Uses

In the United States, annual per capita consumption of wheat had been dropping sharply until about 1960 when we began to observe a leveling off at the 100-to 120-pound level. As a result and because of increasing population, the statistics are now beginning to show an actual increase in total volume of wheat being used for food. Thus the 1964-1966 average food usage was 508 million bushels as against 525 million bushels projected for 1969.

Of course, price is the primary determinant in the usage of wheat for feed. Changes in the wheat support program, beginning with the 1964 crop, have made wheat more competitive with feed grains for livestock and this year with little seasonal rise in prices it is projected that 225 million bushels will have been fed.

What happens in 1970 in the feed area will depend on price, but for food usage it would seem safe to predict another small rise.

Research and Development to Maintain Markets

We have mentioned some of the inputs that affect wheat markets such as price for feed usage and population for food usage. But there is more, and much of it in one word is technology. We can go back one step further and point out that technology depends on the development of fundamental knowledge, and I want to emphasize that we need both.

The food and feed industries are dynamic and fiercely competitive. Computers read out the value of feed fractions down to a fraction of a cent and coldly reject the poorer value alternatives. In the food area newer convenience products push the older "do it yourself" ones off the shelf.

Under such conditions the wheat industry must be flexible, must be in swing with the times if wheat is to retain its markets or improve them. We need to add convenience to our wheat foods--longer shelf life in bread. We need to take advantage of modern marketing facilities such as the freezer display case. We need to lower cost and improve nutrition. For feed wheat we must know its optimum metabolizable energy, its protein availability, and other characteristics, because to underestimate these or not to know them puts wheat at a disadvantage when that cold computer starts computing least-cost formulas.

Such improvements and knowledge come from research and development. This is being strongly recognized by the wheat industry in their effort to establish and fund the Wheat and Wheat Foods Foundation which will be dedicated to a coordinated program of research, education, and promotion.

There are thousands of wheat food products, each with its own manufacturing process and unique characteristics. In the production of San Francisco "sour dough" bread, the proof time is in the order of 7 or 8 hours. How much more capacity could that same plant have if proof time could be cut to say 4 hours. We will hear more on the sour dough later in the conference. The possibilities for new and improved products and processing techniques have never been greater. The role of research and development has never been more important.

Adoptions and Accomplishments of Food and Feed Research

Bulgur.--Bulgur is one of those wheat foods whose origin appears lost in antiquity. The commercial bulgur of today is a product prepared by soaking wheat, cooking it in steam or water with or without pressure, and drying. The bulgur is partially debranned by mechanical means to reduce fiber content and then cracked to a grit. However, long before the development of the commercial product of today, bulgur was a food known and used in the Middle and Near East. Pence (2) has reviewed the history of bulgur. The embryonic beginnings of bulgur production in the United States were in 1892 when the Armeno Cereal Company was founded. Comparatively speaking, however, bulgur remained a dormant giant until 1951 when the Oregon Wheat Commission became interested in the possibilities of bulgur for expanding wheat markets at home and abroad. In 1952 the U.S. Department of Agriculture and the Millers National Federation joined with the

Commission and the ball began to roll. A successful bulgur acceptance demonstration was held in India in 1953. U.S. Department of Agriculture personnel at Beltsville undertook storage stability tests, and processing trials were begun at the Western Regional Research Laboratory at Albany, California, thus beginning the important role of research and development in the transition of bulgur to a large-scale commercial product.

In 1954, the Millers National Federation, Fisher Flouring Mills, and the Foreign Agricultural Service of the U.S. Department of Agriculture developed plans to obtain 500,000 bushels of surplus wheat for processing into bulgur for consumer acceptance tests in rice-eating, Asian countries. Fisher Mills in consultation with the Western Regional Research Laboratory developed a bulgur process (3) and had a 100,000-pound-per-day plant on line in 1955 (process described by Brown (4)). Interest was high, and Fisher soon developed a domestic retail market. In addition, by July 1, 1961, 25 million pounds were sold for dollars overseas.

During this period, the Western Regional Research Laboratory was accumulating comprehensive, basic processing information on the effects of heat, moisture, and other process variables on the soaking, cooking, drying, and other operations in the conversion of wheat to bulgur (5-7). Nutritional aspects and storage stability were studied (8-10). A continuous atmospheric-pressure process for bulgur production was developed (11, 12). New products from bulgur and methods of using bulgur were developed (13-18). The price of processing a pound of bulgur dropped from 3.5¢ (pre-1954) to 1.1¢ per pound. Our modest research costs contributing to this price reduction have been repaid to industry, growers, and the nation a great many times over.

Undoubtedly, this backlog of information was an important positive factor in the decision to include and keep bulgur in the Food for Peace Program that had its beginnings in 1961. It was, of course, the Food for Peace Program that provided the impetus to rocket bulgur production to 60 million pounds in 1962 and an average of about 400 million pounds per year since. We are proud to note that all of the major bulgur producers in the early stages of tooling up and getting underway consulted freely with us and were helped greatly by the processing, composition and promotional information we had developed. But this is not the end of the bulgur story.

WORLD Wheat.--Feedback from recipients in the many countries that received bulgur showed acceptance was rather good in general but that there were objections, particularly from certain Oriental countries, about the dark color and full wheat flavor of bulgur. Researchers at the Western Regional Research Laboratory were responsive to these indications of dissatisfaction and embarked

on further improvements. The result has been a lighter and blander product known as WURLD Wheat--so named to indicate the origin of its development. The developmental research was begun in 1962 and continues today in the form of extensive market testing in cooperation with the Dow Chemical and Cargill companies.

Two basic types of WURLD Wheat (19, 20) can be prepared, a cooked version and an uncooked version. Experience has shown that the cooked product is generally preferred, and therefore I'll restrict further discussion to it.

The first step in WURLD Wheat processing is to soak and cook the wheat. For example, cleaned wheat might be soaked 1 hour at temperatures rising from 135° to 180° F., held for 30 minutes at 180° F., and then steamed 15 minutes at 212° F. The wheat is drained, coated with hot 25 percent sodium hydroxide, intimately mixed and allowed to react for 3 minutes. The reacted wheat is cooled in water, and the lye-loosened bran is removed from the kernel by vigorous water washing. The bran which floats is easily separated. The peeled kernels at about 50 percent moisture are then neutralized in acid before being dried in warm air. In the cooking process, the crease of the wheat kernel opens or butterflies, completely removing the bran and leaving a low-fiber, light yellowish kernel. As the product imbibes water during preparation for eating, it lightens up considerably.

Market testing in the Asian countries with the 16 tons of product we produced in 1968 with the Dow Chemical Company definitely showed a preference for the whole kernel product. But cooking time for optimum eating quality of the whole kernel product was too long, and the resulting product was considered rubbery. The explanation deduced for this is that the aleurone layer of cells was still intact in the WURLD Wheat and presented a physical barrier to rapid water penetration as well as a rubbery mouthfeel. To overcome these problems, WURLD Wheat is now scarified on an abrasive cone (21) which produces fissures in the aleurone and results in a cooking time of 12 to 20 minutes and a softer mouthfeel.

Eighteen tons of the improved WURLD Wheat were produced in our continuous pilot plant in 1969 in cooperation with Dow Chemical Company. The scarified version of the product is being tested in Taiwan, South Korea, Philippines, Hong Kong, and Indonesia with continuing success. It appears that WURLD Wheat is competitive with rice if the price is equal to or less than that of the common grades of rice containing a fairly large percentage of broken. With processing costs estimated at 1 to 1.5¢ per pound, it would seem that WURLD Wheat can be competitively priced. Data from the marketing test are currently being consolidated, and further conclusions will be known shortly.

In the domestic area, International Minerals and Chemical Corporation has been extremely interested in the possibilities of manufacturing prepackaged, prepared WURLD Wheat dishes similar to those in their Village Inn rice line.

Many such recipes for pilafs and assorted WURLD Wheat dishes have been developed at the Western Regional Research Laboratory and a book of these recipes is being prepared.

Frozen bakery products.--An exciting area in which the Western Regional Research Laboratory pioneered is the freezing of bakery products. Bakery products are perishable, and loss of quality begins immediately after preparation. Proper freezing can arrest or slow down deterioration and thus provide the needed time to get the product to the consumer in top quality.

This is a dynamic area with lots of potential--toaster pizza to Danish pastries. From 1960 with sales of \$2.6 billion, the frozen food industry will grow to \$8.9 billion by 1970 (22). Starting in 1954 with a value of \$10 million, frozen bakery products rocketed to sales of \$284 million in 1968 (23). Frozen pizza, not included as a bakery product, advanced in sales to \$125 million in 1968 (23).

With statistics such as these we can understand the observed leveling out of the decline in per capita consumption of wheat, or why total food usage of wheat is increasing. Again, we are proud to have contributed significantly to the trend.

Freezing requirements for bread are quite demanding as shown in research carried out at the Western Regional Research Laboratory in the 1950's. It was shown that at ordinary refrigerator temperatures bread crumb firms rapidly (24), though the opposite is true for cakes (25). To minimize the time at normal refrigerator temperature, breads should be frozen quickly as well as defrosted quickly for maximum retention of quality (26). The conditions necessary for various rates of freezing and thawing (27-30) along with time-temperature-tolerance studies (31-33) were carried out--all timely and vital information for the then embryonic frozen bakery products industry. Through contracts, the USDA extended their frozen bakery foods research to include cake doughnuts, yeast-raised doughnuts (34), dinner rolls, cinnamon rolls (35,36), Danish pastries (37), and frozen fruit pies (38). By speeches at national conferences, technical and trade publications, and innumerable personal contacts, we took our comprehensive research information to the entire baking industry to help found this large segment of the frozen food industry on a solid, secure basis.

In addition, a survey of the baking industry's use of freezing was made and reported (39), aiding the industry in self analysis and pointing out direction and opportunities. An evaluation of bread freezing in bakeries with respect to advantages, techniques, and cost factors was made (40).

More recently, Kline and Sugihara of the Western Regional Research Laboratory studied frozen doughs (41) and elucidated the factors affecting the stability of the yeasts during frozen storage. Methods were developed, many of which are now used in the industry, to improve yeast stability during frozen storage, thus giving the housewife a dough which will proof properly when thawed and bake out into that wonderful product--oven fresh bread.

All of these research efforts have helped overcome the technological problems and have provided one of the important catalysts in the takeoff and continuing success story of the frozen bakery products industry. Again, our research costs have been repaid a great many times over.

The future for increased wheat utilization in this area is most promising. Projections by Quick Frozen Foods and E. I. duPont de Nemours and Company indicate that the class of frozen food products known as "prepared foods," which includes frozen bakery products, will increase in the U.S. to 9.6 billion pounds in 1977, from only 2.7 billion pounds in 1967. On a dollar basis the projected increase is 269 percent or from \$1.6 billion in 1967 to \$5.9 billion in 1977. Much continued research, development, and promotion will be needed to sustain that growth.

Amino acid methodology for wheat and wheat millfeeds.--The computerized, efficient selection of feed formulations depends on reliable and precise nutrient data of the individual feed components. To underestimate a nutritional factor in a feed material such as wheat is the same as selling wheat for less than its worth. Some previous methods for analyzing wheat feed materials for amino acid content have done just this. Researchers at the Western Regional Research Laboratory have developed methods (42) which correct for destruction of serine and threonine during analysis and slow release of valine and isoleucine. It was shown that tyrosine is sensitive to traces of oxygen and requires careful degassing prior to the hydrolysis step. A separate procedure was developed (43) for tryptophane.

Some of these improvements in methodology have already been used to obtain improved amino acid values, reported in the Millers National Federation Millfeed Manual (44). The extent to which this new information has already contributed toward greater use of wheat and its fractions in mixed feeds is impossible to estimate as yet, but no one can argue that it is not significantly helpful.

Wetting and slow drying of wheat to improve feed utilization.

An interesting development from Washington State University work under contract with USDA was the observation with poultry that feed efficiency of water-treated wheat or wheat millfeeds was significantly greater than that of untreated wheat (45). The magnitude of this improvement ranged from 13 to 19 percent. The documentation of this fact has shown poultry raisers how to get more value from wheat.

Wheat protein concentrate.--About 5 million tons of wheat millfeeds containing 800,000 tons of good quality protein are produced in the United States each year. The Western Regional Research Laboratory developed a dry milling and screening process (46) that allows the recovery of 20 to 40 percent of certain millfeeds as a high-protein, low-fiber flour known in the trade today as Wheat Protein Concentrate or simply WPC. When obtained from hard wheats, WPC contains more than 20 percent protein and less than 3 percent fiber. The protein has about twice the lysine content (47) of standard white flours, which results in a respectable protein efficiency ratio of about 2.0. The WPC contains a wealth of the various B vitamins. It has a strong wheat flavor and therefore has generally been used in conjunction with other more bland materials.

One such product developed was Flour Blend A: 70 percent straight grade flour, 30 percent WPC, fortified with Vitamin A and calcium carbonate. Twelve million pounds of Flour Blend A were purchased in early 1968 under the Food for Peace Program and sent in large part to India and Ceylon. Lengthy time in storage and transit resulted in high fat acidity and bitterness, causing some complaints from the recipient countries. Further requests for purchase have been received but not activated because of the necessity to await resolution of these problems.

The storage stability of Flour Blend A was studied (48) at WRRL, and it was found that at 13-percent moisture there is considerable lipase activity. Concomitant with increase in fat acidity due to lipase, there is a loss of baking quality which can best be measured by reduction in loaf volume. At 13-percent moisture, Flour Blend A remained acceptable for bread use for 6 months at 70°F., 4 months at 90°F., and only 1 month at 100°F. Reduction of the moisture content to 9 percent increased acceptability to 6 months at 90°F. and 4 months at 100°F. These considerations are of concern chiefly in overseas shipment. The rapid delivery and turnover of flours for the U.S. baking industry preclude problems for Blend A products provided they are made from fresh material.

At present, studies are being conducted to determine conditions necessary and means of inactivating enzymes in WPC to improve its long term storage stability but retain its usefulness in baked goods. One device constructed is a fluidized bed where temperature and moisture can be controlled. Because the WPC flour particles are entrained in the hot air stream, very rapid heat transfer is obtained. Work is just under way but it shows that lipase can be gradually destroyed at 185°F. and a product moisture of about 8 percent. Steam pelleting is also being investigated.

A second product containing WPC is known as Wheat-Soy Blend or simply WSB. This is a child food supplement presently being used in modest but steady amounts in the Food for Peace program. Ingredients for WSB are wheat flour which may be straight grade flour or bulgur flour, WPC, soy flour, and stabilized soy oil, supplemented with vitamins and minerals. WSB is a precooked product and to insure that all components of the final product have received sufficient heat treatment to inactivate enzymes, a test for peroxidase enzyme activity in the final product is specified. Storage stability tests indicate generally good stability against build-up of free fatty acids and oxidative rancidity. The antioxidants incorporated in the soy oil are probably in large part responsible for the stability against oxidative rancidity. Biological testing shows WSB to have a protein efficiency ratio of 2.4 compared with 2.5 for milk casein.

Several U.S. milling companies have made, are making, or have the capability of making WPC. Pillsbury offers for sale two types of WPC: one that is prepared by the roller milling and screening process, the other by turbo milling and air classification. The latter is generally a little higher in protein and very low in fiber. One of Pillsbury's customers has been a pet food manufacturer. Interest continues on ways to capitalize on this unique product. General Mills, Cereal Division, is exploring ways of utilizing WPC in "nutritional-type" products. Consideration is currently being given to using Flour Blend A bread in a school lunch program in Arkansas.

WPC has come a long way but considerably more developmental research is needed to reach its ultimate potential in the market. This work is continuing at WRRL.

Summary

I've discussed today some past developments at the Western Regional Research Laboratory and pointed out some of their commercial significance. We talked about bulgur and WURLD Wheat, frozen bakery products, wheat protein concentrate, and improved methods for amino acid analysis in wheat. There are others but let it

suffice to say that research has been productive and with the complexity of society increasing, research and development will be more important than ever before.

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INDUSTRIAL ALCOHOL FROM WHEAT

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Ethyl alcohol is a member of a series of related alcohols--methyl, isopropyl, butyl, and amyl--that have many and varied uses. This evaluation of ethyl alcohol concerns its production, its markets, and particularly its possible use in motor fuels.

Ethyl alcohol has been used by men since the dawn of civilization. Originally, it was produced by the spontaneous fermentation of sugars and was consumed by ancient races for its intoxicating effects. The Arabs and Romans learned to isolate the alcohol and to employ it industrially in the preparation of perfumes, cosmetics, and medicines. Over the intervening centuries the production and purification of alcohol have advanced to their present high level.

Today, production of ethyl alcohol is based on two major procedures, namely, fermentation and chemical synthesis. The most important raw materials for each procedure are as follows:

Fermentation.--Cereal grains (corn, wheat, barley, sorghum, or rye); sugarcane (molasses); sugar beets; fruit product wastes; other starch crops (potatoes or rice); sulfite liquors (paper); wood and cellulose-containing materials.

Chemical Synthesis.--Petroleum and natural gas; coal; oil shales and sands.

More than 93 percent of ethyl alcohol produced in the United States is now prepared from cereal grains or from petroleum-based raw materials (1). Synthetic alcohol from petroleum has captured practically all the industrial alcohol market of 300 million gallons or more annually. Let us compare these two major types of raw materials and their potentials.

Fermentation

Ethyl alcohol is produced by the action of yeast on the starch and sugars present in the natural raw materials. Cereal grains, including wheat, contain large amounts of starch.

Until about 1929 practically all ethyl alcohol was produced from grains, molasses, and materials high in sugar or starch. All beverage alcohol is still produced by law in the United States by

the fermentation of natural products. About 130 million bushels of grain (mostly corn, rye, barley) are used annually in this market. Grain is no longer used for industrial ethyl alcohol because it is not economical.

It should be emphasized that for industrial use synthetic alcohol is not purer or better than fermentation alcohol. Chemically, for practical purposes, both alcohols are the same.

During World War II (1942-1945) wheat significantly shared in the alcohol market (fig. 1). In 1943 alone some 100 million

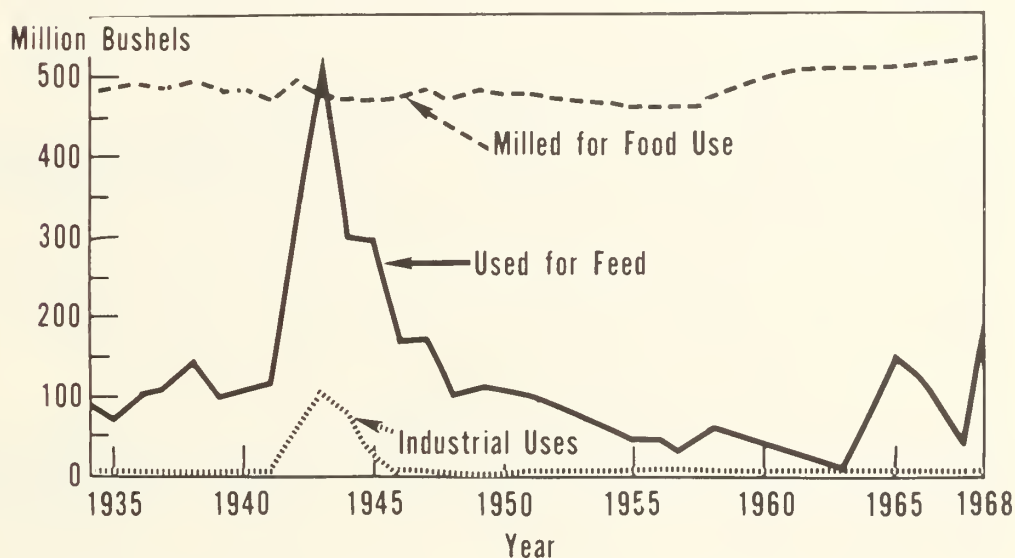


Figure 1.--Utilization of wheat in the United States.

bushels (equivalent) were consumed, and a total of at least 250 million bushels of wheat were used during the war period. The price of wheat during this emergency was of minor importance since other raw materials, including petroleum, were in short supply, and the need for alcohol was critical. Today, only about 4 million pounds of byproduct flour (equivalent to flour from less than 100,000 bushels of grain) are used annually in the production of ethyl alcohol, and practically all of this alcohol goes into beverage use. The suitability of wheat as a raw material technically has been demonstrated by actual experience. Its use is entirely a question of economics.

The conversion of the starch and sugars to ethyl alcohol is shown in figure 2.

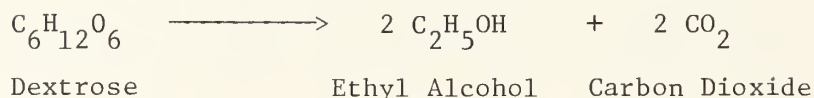
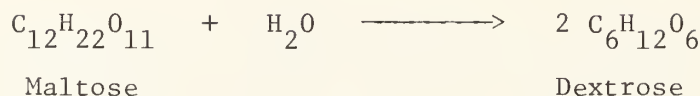
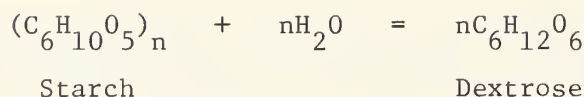


Figure 2.--Conversion of starch and sugars into ethyl alcohol.

Thus, 180 pounds of dextrose theoretically should yield 92 pounds of alcohol. For starch, the theoretical yield of alcohol is 0.568 pounds per pound of starch. In actual practice yields generally are about 90 percent of theoretical.

Alcohol production is directly related to the starch in the grain. If, as shown in table 1, the respective starch content of

Table 1.--Average percentage composition of surplus cereal grains^{1/}

Grain	Starch	Protein	Oil	Fiber	Minor constituents ^{2/}
Hard wheat	64	14	2	2	18
Soft wheat	69	10	2	2	17
Dent corn	72	10	5	2	11
Sorghum	71	13	3	2	11

^{1/} Moisture-free basis.

^{2/} Minerals, sugars, pentosans, and vitamins.

a hard wheat and soft wheat is 64 and 69 percent (moisture-free), the maximum alcohol that could be produced from a 60-pound bushel would be 21.8 and 23.5 pounds. Translated to a 14-percent moisture basis and a practical 90-percent yield of alcohol the anhydrous alcohol obtained per bushel would be 16.9 and 18.2 pounds, respectively, or 2.58 and 2.75 gallons.

The cost of ethyl alcohol from wheat depends on many conditions, such as location, regional labor rates, and wheat used. Past studies (2) have shown that a practical-size grain fermentation plant will process about 20,000 bushels per day. Such a plant at current prices would cost about \$12 million to construct. Anhydrous alcohol production would be about 17.2 million gallons from 6.6 million bushels of wheat. A representative cost estimate is shown in table 2.

Table 2.--Fermentative conversion cost of 190° proof
alcohol from wheat
(Exclusive of cost of wheat)

Item	Cost/gallon cents
Base conversion cost	26.8
Depreciation (\$1.2 million/year, 10 years, 17.2 million gal.)	7.0 33.8
Byproduct feed credit (6 lb./gal. alcohol at \$52/ton)	15.6
Net	18.2
<u>Conversion cost of 200° proof alcohol</u>	
Alcohol (1.048 gal. at 18.2¢)	19.1
Cost of dehydration	1.9
Total cost, exclusive of wheat, profit, packaging, and sales expenses	21.0

The wheat cost per gallon of alcohol would depend directly on the wheat price as shown in table 3.

There are other possibilities for wheat to be used to make alcohol. Conversion of wheat flour into gluten and starch and then fermentation of the starch have been considered. About 250 million pounds of flour is now processed annually to gluten (equivalent to flour from about 5,700,000 bushels). But this gluten market today is quite limited. An urgent worldwide demand for wheat gluten could possibly change the situation, at least on a limited scale. However, at current gluten prices (approximately \$0.30/lb.) and markets, it is generally more economical to ferment whole grain than to convert the byproduct starch into alcohol.

Table 3.--Effect of wheat cost on ethyl alcohol cost
(Basis: 2.6 gallons 200° proof alcohol/bushel)

Wheat price/bushel Dollars	Alcohol cost/gallon		
	Wheat	Conversion	Total base cost ^{1/}
	-Cents-		
1.00	38.5	21.0	59.5
1.25	48.0	21.0	69.0
1.50	57.7	21.0	78.7

^{1/} These costs do not include profits, packaging, and sales expenses.

Chemical Synthesis

Practically all synthetic alcohol is now produced from ethylene, which is obtained from petroleum and natural gas. The original commercial synthetic process involved the reaction of ethylene with sulfuric acid and hydrolysis of the ethylsulfate to ethyl alcohol. The direct catalytic hydration of ethylene with water is the newer process and is increasingly used. Conversion yields of ethylene to alcohol as high as 97 percent have been reported (fig. 3).

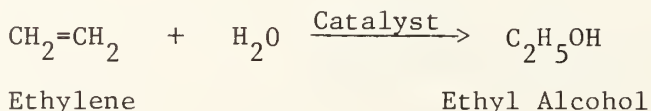


Figure 3.--Conversion of ethylene into ethyl alcohol.

Commercial experience (3) has shown that a pound of ethylene will yield about 0.25 gallon of 190° proof alcohol. Most new synthetic plants have a yearly alcohol capacity in the order of 50,000,000 gallons. At present, such a plant would cost approximately \$25 million (2). Under these conditions, the alcohol conversion costs would be as shown in table 4.

Table 4.--Synthetic conversion cost of 190° proof
alcohol from ethylene
(Exclusive of cost of ethylene)

Item	Cost/gallon cents
Base conversion cost	11.0
Depreciation	
(\$2.5 million/year, 10 years	
50 million gallons)	<u>5.0</u>
Net	16.0
<u>Conversion cost of 200° proof alcohol</u>	
Alcohol (1.048 gallons at 16.0¢)	16.8
Cost of dehydration	<u>1.9</u>
Total cost, exclusive of ethylene, profit, packaging, and sales expenses	18.7

Ethylene charges vary depending on location and included expenses.^{1/} The effect of ethylene price on alcohol cost is shown in table 5. To compete with these alcohol costs by fermentative production the wheat used would have to be priced at less than \$0.50 per bushel.

^{1/} Present quoted price is 3.0 to 4.0 cents per pound.

Table 5.--Effect of ethylene cost on ethyl alcohol cost

Item	Ethylene, cents/pound		
	3.0	4.0	5.0
	Cost/gallon, cents		
<u>190° proof alcohol</u>			
Ethylene	12.0	16.0	20.0
Conversion	16.0	16.0	16.0
Total manufacturing cost/gallon (exclusive of profit, packaging and sales expenses)	28.0	32.0	36.0
<u>200° proof alcohol</u>			
Ethylene	12.6	16.3	20.9
Conversion	18.7	18.7	18.7
Total manufacturing cost/gallon (exclusive of profit, packaging and sales expenses)	31.3	35.0	39.6

Markets

Domestically, the market for industrial ethyl alcohol is now more than 300 million gallons per year (4). The market has been static for several years. Synthetic alcohol has captured it and raw material supplies are adequate for the foreseeable future. Can a new alcohol market be developed and, if so, can agriculture and particularly wheat share in it? The immediate consideration is the huge and growing automobile motor fuel market.

Annual consumption of gasoline for automobile fuels is about 85 billion gallons (5). Tetraethyl lead (TEL) is a major additive used in more than 97 percent of all motor fuels. Some 650 million pounds of TEL are consumed annually in the United States (3). TEL fluids increase the octane rating of gasolines regardless of the base fuel octane rating. Refinery technology has advanced since World War II so that fuels of practically any required octane rating for the latest automobile engines can be produced direct without TEL. However, ethyl fluid is still used because it is more economical to obtain the increase in this manner. Ethyl alcohol would contribute little, if any, octane increase to present motor fuels.

Lead contributes to air pollution and, from the first, its use in motor fuels has been a controversial subject. Reported toxicity threshold limit for TEL is 0.075 mg./m.³ of air (approximately 60 p.p.m.) (3). If this limit is accepted, there is a

safety factor of about 10 in the leaded gasoline vapors, and the factor would increase several times in the burned fuel vapors. However, with the increased emphasis on pollution control, and the many uncertainties and controversies over TEL, its use might be eliminated by law sometime in the future.

Ethyl alcohol has been used as a component in U.S. motor fuels on a limited test scale only. Alcohol will give acceptable blend and handling performance, provided the blend contains at least 10 percent anhydrous alcohol (by volume). Lower blends might also be used with dual and more expensive fuel systems. The basic problem has been unfavorable economics. Legislative action that would require the use of alcohol blends with the alcohol produced from cereal grains (i.e., wheat) would be required for a significant volume motor fuel alcohol market.

The effects of such a legislative market are tremendous. It would require more than 3.2 billion bushels of cereal grains annually (the 1968 cereal production of wheat, corn, and sorghum was approximately 1.57, 4.37, 0.74 billion bushels, respectively) to produce the 8.5 billion gallons of anhydrous alcohol (10-percent blend). This alcohol would cost more than \$5.0 billion to produce from \$1/bushel grain. Approximately 500 fermentation plants with a total capital investment in the order of \$6 billion would also be required. (Present capacity is only 15 to 20 million bushels.) About 25 million tons per year of byproduct feed would be produced.

The significant effects of the 25 million tons of byproduct feed produced on the markets for other grains and cereals have not been evaluated. These high protein byproduct feeds would not fill the gap left by removal of a high proportion of feed grain from the market. These byproduct feeds would also compete with such protein concentrates as soybean meal, cottonseed meal, and other feed concentrates. Basically, there would be an excess of protein feeds but not enough carbohydrate energy.

Opposition to the forced use of alcohol from grain in all motor fuels by the petroleum industry and the urban population as a whole would undoubtedly be severe. If the grain was provided free, a 10-percent blend would add more than one cent per gallon to the present wholesale gasoline price. Grain at \$1 per bushel would add at least five cents per gallon. TEL additive now costs less than one cent per gallon and equivalent improvement by direct refining would cost three to four cents per gallon.

Depletion of the world's oil and gas supplies is not predicted for a long time. Proven world gas reserves in 1967 were estimated at about 1,000 trillion cubic feet--or about a 25-year supply (6). Since then, the North Slope area of Alaska has been estimated to contain some 40 billion barrels of oil and 250 tril-

lion cubic feet of gas. Other estimates place the Arctic supply at several times this amount. In addition, vast amounts of heavy oil are locked in shale and oil sands, and its recovery is under pilot study in the United States; a plant is operating in Canada. Production of pipeline gas from coal is also under pilot study.

Oil and gas costs are expected to gradually increase due to inflation, increased exploration and delivery costs, and possible international problems. The present U.S. oil price is about \$3.20 per barrel (42 gallons) and in some world regions (Near East) is about \$1.80 per barrel. A U.S. price in the predictable future up to \$5 per barrel is possible. We could also expect the ethylene price and hence the synthetic ethyl alcohol price to increase at about the same inflation rate; however, it has not done so in the past. Present ethylene prices are 3.0 to 4.0 cents per pound and published prices are about 3.25 cents f.o.b. the production site (7).

Summary

(1) Practically all industrial ethyl alcohol now produced in the United States comes from petroleum raw materials. Synthetic alcohol costs less to produce than fermentative alcohol.

(2) Beverage alcohol in the United States must by law be prepared from cereal grains or other natural products.

(3) The production of ethyl alcohol from wheat and other cereal grains by fermentation is technically feasible and has been proven in actual operations. The alcohol is equal to synthetic alcohol in quality and performance.

(4) Use of ethyl alcohol from wheat as a required component of all automotive fuels would require national legislative action. The cost of the finished fuel would be higher than fuels now available from petroleum.

(5) An alcohol-gasoline fuel blend must contain at least 10 percent alcohol for acceptable handling and use performance. Lower blends might be used with a dual fuel system. A 10-percent blend in all motor fuels would require about 3.2 billion bushels of grain per year to produce the 8.5 billion gallons of required alcohol. Plant capital investments to produce this amount of alcohol would be at least \$6 billion. Guaranteed long-term markets and stable prices would be required for such investments. Utilization of the 25 million tons of byproduct feed--which contains the original protein, but from which most of the energy has been removed--has not been evaluated.

(6) There is no predictable shortage of motor fuels or petroleum raw materials in the foreseeable future.

(7) Production of additional fermentative ethyl alcohol on a small scale from byproduct cereal fractions, or where valuable markets exist for special byproducts, may be feasible for certain isolated locations. Practically all such alcohol is now sold for beverage purposes.

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PULP AND PAPER FROM WHEAT STRAW

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Worldwide demand for paper and paperboard in the next 15 years is expected to double (1). Although wood will retain its predominance, the pendulum is expected to swing slowly towards increased use of agricultural fibers. These nonwood fibers may be established raw materials as cereal straws, bagasse, and bamboo or may be new annual crops like kenaf, rosella, or sorghums.

Nonwoody fibers are now the raw material for about 3 percent of the total pulp and paper production in the United States. Yet, total usage of pulp is so large that this 3 percent represents about 1.6 million tons per year (2). The annual per capita consumption of paper is about 525 pounds and is growing at a rate paralleling the increase in Gross National Product.

Wheat straw was formerly an important pulping raw material in the United States. The first U.S. paper mill in which wheat straw was the raw material was installed about 1831 in Chambersburg, Pennsylvania. Its capacity was about one ton per day. At one time, there were at least 30 plants that used wheat straw as their raw material. As late as 1950, more than 650,000 tons of pulp were produced annually from straw (3). Major use of the straw pulp was for strawboard, egg-case fillers, and corrugating paper. Wheat straw has no significant market for these purposes now. The reasons for this change and the hopes for future possibilities are briefly reviewed.

Background Information

The total amount of wheat straw in the fields has not materially changed for many years. (To date, the newer wheat semi-dwarf varieties have had only minor overall effects in most regions but could be significant in the future.) However, the location and condition of the straw have completely changed. With modern farming practices, the wheat grain is mechanically recovered in the field and the straw is left behind and distributed on the ground. Straw is no longer available at a low cost in straw stacks at central locations. Collection thus becomes a separate operation. The straw cost and the supply available in collected form have thus become undependable.

The original straw-based plants were located in the Eastern Midwest. Relocating plants to follow the shift in straw supply

westward was not feasible. Therefore, as the pulping plants became obsolete, they were dismantled or were more economically modernized to use readily available wood. Many of these older straw plants were also too small for efficient economical operations by today's standards.

Present Situation

Today there appears to be an increasing need in the United States for nonwoody fibers. There is some disagreement on the adequacy of future wood supplies. Even if sufficient wood could be grown, however, the cost of cutting and delivering it to the mills is on the increase. Wood cutters are in short supply and will not work in remote areas at competitive labor rates. Several paper mills have already reported wood shortages during certain yearly periods because of insufficient deliveries.

The tremendous investment in woodlands is also a problem, particularly as land prices, taxes, and operating costs increase. Wood yields per acre are normally 1 to 2 tons per year. However, trees must be grown at least 5 to 10 years before they can be harvested. Thousands of acres (particularly in the South) are already being converted to the production of annual crops.

Feasibility studies on straw pulping have been made and published by several States, among them Colorado, Kansas, Nebraska, North Dakota, and South Dakota. In general, all these studies show that sites are available in each State where water, straw, labor, land, and most other basic requirements for large straw pulping plants could be met. Pulping plants do not exist in these regions and locations now. The basic situation to resolve is whether it is economical to install such plants and, if so, how to proceed. First, since the technical and economic information on straw pulping is obsolete, it must be brought up-to-date before making any decisions.

Future Situation

There is now an adequate supply of wheat straw for a pulp plant in several United States' locations. Only a fraction of 1 percent of the over 100 million tons produced annually is collected for commercial use. Adaptation of the combining operation would be required to simultaneously collect the straw in a suitable form (i.e., bales) for most economical transportation to the processing plant.

Present trends in the pulp and paper industry and preliminary studies on straw-based plants have indicated that only a large, continuous, automated plant is economically feasible. Unit costs increase rapidly below 200 tons per day, and plants

with larger capacity reflect some further economic advantage but at a decreasing unit rate.

U.S. Department of Agriculture research on agricultural residues (including straw) was discontinued about 10 years ago. The order of magnitude cost information below illustrates the effects of certain variables on process and product costs. It is based on a hypothetical, integrated, continuous, straw-pulping and corrugating-board plant located on an unspecified site in a major wheat production region.

Wheat straw board. Plant size vs. board cost

Production, tons/day	75	150	225
Capital cost, million dollars	9.04	12.3	15.6

<u>Board cost</u>	<u>Dollars per ton</u>		
Straw (\$16/ton)	29.9	29.9	29.9
Manufacturing costs	88.1	65.5	59.3
Fixed costs	50.7	34.8	29.8
Total factory cost	168.7	130.2	119.0
(Exclusive of sales and profit)			

The effects of plant capacity on paperboard cost are shown in figure 1.

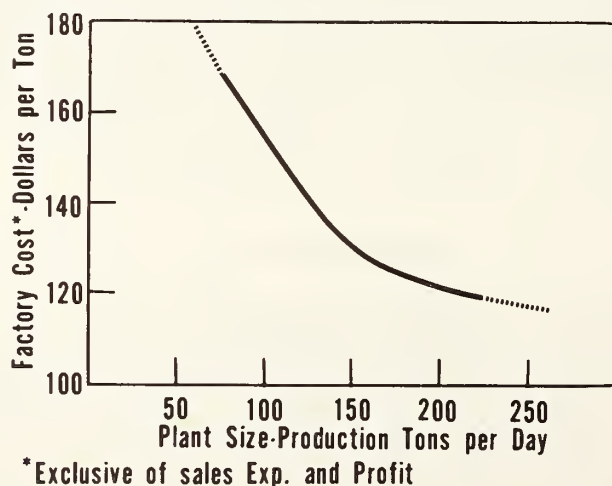


Figure 1.--Wheat straw board. Plant size vs. board cost (hypothetical plant).

For example, the cost for board in the order of \$168 per ton in a 75-ton-per-day plant is reduced to about \$130 per ton in a 200-ton-per-day plant. Capital cost per ton of capacity is also reduced by about 35 percent. Present paperboard wholesale prices are in the same order of magnitude as in the 200-ton plant.

The effects of straw price on board price are shown in figure 2. A change of \$1 in straw delivered price changes the

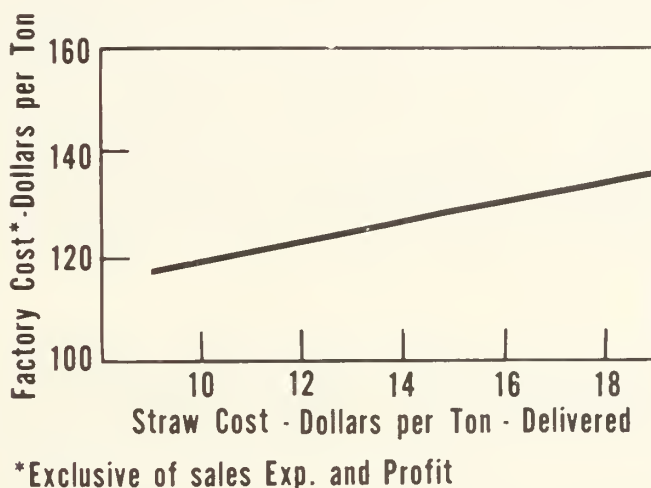


Figure 2.--Wheat straw board. Straw cost vs. board cost (150-ton-per-day hypothetical plant).

board price about \$1.86 per ton. This effect is practically the same (regardless of plant size) in a large continuous plant.

Summary

Suggested procedures for determining the feasibility of straw-based pulp and paper plants and steps to carry out an installation are as follows:

- (1) An identifiable group, possibly a co-op, must be formed to contract for and guarantee an adequate future wheat straw supply on a regular basis. This contract can allow for future price adjustments, but the price must be stable with only minor fluctuations yearly.

- (2) This identifiable group, or an industrial company, must decide on a general region for a plant location and its size, and contract for a detailed economic feasibility study for that region.

The best location site would be determined from this study. Engineering firms are available for such contract studies.

(3) Markets and disposition of the finished products must then be resolved. If possible, some assurance of contracts for future production should be obtained, based on preliminary estimates of production costs and selling price.

(4) If market economic studies are favorable, plants must be designed in adequate detail for firm capital and product cost estimates. Technical know-how exists to make such designs, and there are existing qualified firms who would make such studies.

(5) If results from the previous listed surveys and other associated studies are favorable, a decision on plant construction and timing can be made. If possible, contracts for supplies and products should be obtained. (If one or more of the major customers are major owners of the new plant, its security in times of low market demands would be greatly improved.) A plant without a firm market is subject to higher risks.

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Note: "A Bibliography of Selected Publications on Straw" can be obtained from the Northern Regional Research Laboratory, Peoria, Illinois; also a list of State studies on straw pulping is available.

CARRYING CAPACITY OF U.S. WHEATS FOR EUROPEAN WHEATS

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This report is based on work done at Kansas State University under contract to the Western Utilization Research and Development Division of USDA. Numerous members of the Department of Grain Science and Industry worked on the project at different times. I will mention only John Shellenberger and Otho Skaer, who had the major responsibilities.

Background.--Western European wheats characteristically are low-protein wheats, usually "weak" for bread production. Consequently imported wheats can improve the baking performance of flours, as well as increase the supply of wheat.

For a long time, high-protein spring wheats from North America seem to have been accepted as the most desirable type for this purpose. Spring wheats clearly have an advantage in average protein content over winter wheats. The spring wheats also have contributed sufficient tolerance and adaptability along with "strength" to fit readily into a variety of bakery practices. However, considerable amounts of winter wheat of intermediate protein content have been used in Europe too. This is sometimes referred to as "filler" wheat, implying that it is usually used along with some spring wheat in the mix and does not modify baking performance significantly.

It seemed to us that this implication might not be justified; after all, much of the bread baked in the U.S. contains no spring wheat. Questions on blending value arise on other grounds too. The baking industry in Europe, as in the U.S., has been changing in mechanization, distribution practices, and types of products. In the U.S., winter wheat varieties continue to change. Everywhere the control on performance and costs is tighter. Consequently, an examination of the performance of U.S. hard red winter wheats in blends with European wheats appeared to be in order, and so the project at Kansas State was begun.

The experimental observations are so numerous that only a small fraction of them can be reported here. Because those chosen will have to be illustrative only, a summary of the results and conclusions will be given first.

Summary.--In general, blends improved in baking properties as the protein content of the added North American flour increased, in agreement with accumulated technical and commercial experience. However, hard red winter and hard red spring wheats were equally effective on a "per unit of protein" basis. This was shown most clearly by two baking procedures with which average loaf volume increased steadily with protein content. Tests in which protein level was less of a factor gave less consistent results but failed to indicate that spring wheat flours were superior to winter wheat flours of the same protein content.

Poor-baking European flours tended to give large responses, regardless of protein content, and often were improved as much by lower-protein North American supplementary flours as by high-protein ones. Thus, protein content alone is frequently inadequate for selection of the best supplementary wheats.

We believe that the improvements observed in blends with winter wheats show that the term "filler" wheat does not indicate their full usefulness.

Those are the general conclusions. Some of the planning considerations, the experimental outline, and selection of materials and methods which led to these conclusions were as follows.

Experimental approach.--The gross effects of adding hard to soft wheat flours are matters of common experience to millers and bakers, but the precise responses to be expected are not predictable. For example, one European reference states that a wheat blend for bread flour should contain at least 11.4 percent protein, should have a sedimentation value of at least 25, but then adds that it must in addition have "good baking properties." As a result, the blending or carrying capacity of a strong wheat still has to be defined in terms of the improvements in dough properties and in end-product quality that it will give when added to a poor wheat or flour. In addition to the unpredictability of the behavior of blends, difficulties also arise in selecting the specific characteristics that should be considered important. A study of this kind could easily have led to the inclusion of unmanageable numbers of samples and tests. Obviously some practical compromises had to be made.

A minimal course was chosen with respect to the proportion of strong and weak flours combined in blends--all were made of 25 percent North American wheat flour and 75 percent European. Technologically, 25 percent of a stronger flour is enough to show an effect if it is to be useful in blending. Economically, 25 percent apparently is as much as can be justified.

Thus only one ratio of base to blending flours was used, but each blend was evaluated by several methods. Baking performance was checked by four methods, designated English, French, German, and an American Association of Cereal Chemists (A.A.C.C.) method for the U.S. The European market is not a one-product or one-processing-method market, and the adaptability of U.S. wheats to variations in processing seemed important.

While one may question how typical of the particular countries the baking methods were, they surely provided four widely different evaluation methods. In formula, for example, the French method was simplest, containing only flour, water, yeast, and salt. The English formula was similar but with 2 percent sugar added. The German formula added 1 percent of shortening, and ascorbic acid as a maturing agent. The A.A.C.C. formula was "rich," containing 5 percent sugar, 4 percent nonfat dry milk, 3 percent shortening, and bromate as a maturing agent. There were equally significant differences among the four methods in the mixing development and fermentation of doughs, so the baking methods were certainly diverse.

Dough tests included Farinograph mixing curves and expansion of a dough bubble in the Alveograph. Laboratory tests included the Hagberg falling number test as an indication of the presence of sprouted wheat.

A middle course was followed with regard to number of samples. To obtain samples as representative as possible of the European wheats with which imported wheats would be blended, the samples were obtained from European milling companies with the request that they supply their mill blend of domestic wheat. These samples were obtained from both 1964 and 1965 crops, one sample per year from each of eight countries. North American wheats were represented by seven samples. Several terminal export grain elevator companies supplied 100-pound samples of different classes and different protein levels for compositing.

Wheat sample characteristics.--Table 1 describes the North American wheats. There was a series of 4 winter wheats ranging in protein from 9.8 to 13.7 percent, and for comparison there were 3 spring wheats, two equalling the highest-protein winter wheat and one exceeding it in protein content. Note that of the 3 wheats of 13.7 percent protein, the two spring wheats had a definitely higher sedimentation value than the winter. Also note that the falling number values for all the winter wheats exceed those of any of the spring wheats by substantial differences. Flour yields were higher for the 13.7 percent-protein springs than for any of the winter wheats.

Table 1.--Characteristics of North American wheat samples

Item	U.S.		U.S.		U.S.		U.S.		Canada	
	No. 1 HYHW	No. 1 HHW	No. 1 HHW	No. 1 HDHW	No. 1 DNS	No. 1 HDNS	No. 1 HDNS	No. 1 HDNS	No. 1 HDNS	No. 1 HDNS
Protein content, pct.	9.8	11.2	12.0	13.7	13.7	13.7	13.7	13.7	14.5	14.5
Sedimentation value	21	35	39	48	65	65	65	65	68	68
Falling number	579	716	747	876	493	493	493	500	492	492
Flour yield, pct.	70.8	69.7	68.8	68.3	74.6	74.6	74.6	73.0	67.7	67.7

Table 3.--Characteristics of European wheats and flours

Crop Year	U.S. grade	Protein Pct.	Sedimentation value	Falling number	Loaf volume ^{1/}	
					Sec.	Cc.
1964:						
Average Range	-- No. 1 HDNS to No. 3 HW	10.6 9.2 to 12.5	32 17 to 65	413 232 to 638	700 652 to 790	
1965:						
Average Range	-- No. 1 HNS to No. 4 SRW	10.6 9.5 to 11.9	30 18 to 52	271 151 to 458	633 485 to 755	

^{1/} A.A.C.C. method.

Flours were used in blending, rather than wheats, and some of their characteristics are shown in table 2. The difference in

Table 2.--Characteristics of flours from North American wheats

Source	Protein content	Farinograph absorption	Valori- meter	Loaf volume (A.A.C.C. method)
	<u>Pct.</u>	<u>Pct.</u>		<u>Cc.</u>
9.8-pct. protein				
U.S. winter	8.6	58.5	22	743
11.2-pct. protein				
U.S. winter	10.1	63.2	53	734
12.0-pct. protein				
U.S. winter	10.9	65.0	57	766
13.7-pct. protein				
U.S. winter	12.7	67.2	58	750
13.7-pct. protein				
Canadian spring	12.9	64.4	59	992
13.7-pct. protein				
Canadian spring	12.9	63.8	66	960
14.5-pct. protein				
Canadian spring	13.7	65.0	80	960

protein content between wheat and flour was slightly larger for these winter wheat samples than for the spring. The absorption of the 13.7-percent protein winter wheat flour was definitely higher than that of the flours from the two spring wheats of equal protein. The most striking difference, however, is the relatively poor loaf volume, 750 cc. by the A.A.C.C. baking method, of that winter wheat flour compared with the 992 and 960 cc. of the spring wheat flours.

Some characteristics of the European wheats and their flours are shown in table 3. The protein range requires explanation. In 1964 the Swiss sample graded No. 1 heavy dark northern spring and contained 12.5 percent protein. There was some spring wheat grown in Switzerland under a government-supported trial program, and the Swiss mill decided to supply some. Without the Swiss sample, the upper limit of protein was 11.6 percent in 1964. The other samples show a moderate range of protein content, grade, etc. In general, the samples were fairly sound wheat, and the falling numbers suggest relatively little trouble with sprouting.

The 1965 samples were different. Protein levels were about the same--the average is the same for the two years, and without the Swiss sample the upper limit was 11.3 percent; but the grade designations and falling number values show that the wheats were less sound than in 1964. A wide range of properties thus was found in the two crop years.

Experimental results and evaluation.--Presentation of the mass of data from the 135 samples and blends in quickly comprehensible form is a problem. One approach we used was to assign "units of improvement" to each of the blending flours on the basis of results from each test. For example, with the A.A.C.C. baking test a 15 cc. increase in loaf volume for a blend over the European base flour was considered to be one unit. The improvement units then ranged from -3 for the lowest protein flour added to a European flour of higher protein content, to +11 for the highest protein winter added to a weak European sample.

A partial presentation of the A.A.C.C. baking test results handled this way is shown in table 4. Columns for three of the wheats have been omitted to lessen crowding. The totals for the North American samples show an increase with protein content; but they also show that the 13.7-percent protein winter wheat is about as useful in increasing loaf volume as the spring wheats on an equal-protein basis.

The improvement frequency totals show differences among the European base flours as would be expected. For example, the Austrian samples were "improved" by 15 units total, while other samples of lower protein and falling number totaled many more units, with the Dutch adding up to 83.

This sort of evaluation was made for all the physical dough measurements and baking tests. For each one, the set of North American flours then was ranked on the basis of the totals. The rankings fell in order of protein content with the A.A.C.C. baking test, as already shown, and also for the German baking method and for the Farinograph evaluations. Results from the English and French baking tests departed from that order; but the winter wheats then compared even more favorably with the spring wheats.

The complete set of these rankings, as well as the experimental values on which they are based, are included in a publication that is now available. Its title is "A Study of U.S. Wheats as Supplements for Western European Wheats in Breadmaking." They are available from our Laboratory; ask for publication ARS 74-52.

In that more complete report you will find that measures of improvement other than loaf volume also were used--bread scores in particular. The trends of results are essentially the same as those found with loaf volume.

Another approach to summarization of the results was tried too. In figure 1, each point shows the average loaf volume increases by the A.A.C.C. baking test for all the European samples when blended with a single North American flour, plotted against

Table 4.--Response of baking performance of European flours to blending with North American flours (results by the A.A.C.C. baking test method, evaluated by the "improvement frequency" method).

European wheat and Crop Year	Flour protein Pct.	Improvement frequency for blend with flour from--			
		9.8-pct. protein U.S. winter	13.7-pct. protein U.S. winter	13.7-pct. protein Canadian spring	14.5-pct. protein Canadian spring
Austrian:					
1964	10.1	1	4	3	5
1965	10.3	-3	1	-1	2
Belgian:					
1964	8.0	2	4	4	7
1965	8.4	0	0	3	5
English:					
1964	8.8	1	3	3	4
1965	9.5	8	10	9	9
Total		20	62	68	91

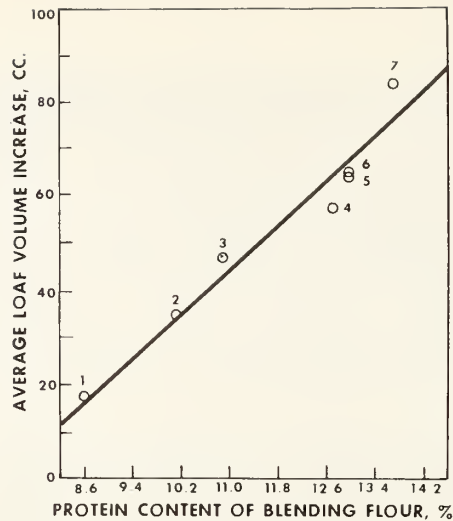


Figure 1.--Relationship of average loaf volume increase of European flours to the protein content of North American flours with which blends were made (A.A.C.C. baking method).

the protein content of that blending flour. When averaged from the responses of the 16 European samples, the effect of protein content of the blending flour is clear and strong.

That considerable variations occur independent of the protein content is shown in figure 2. Here the 1964- and 1965-crop

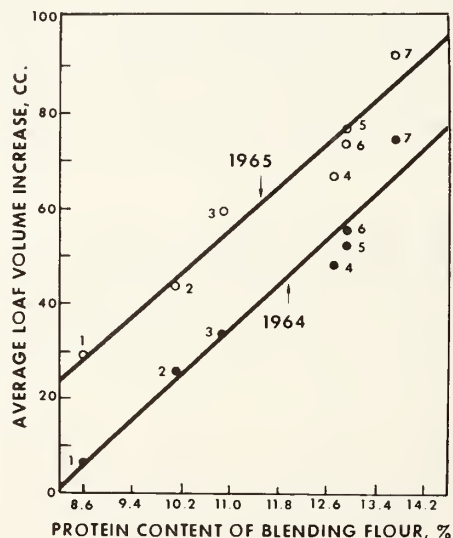


Figure 2.--Relationship of average loaf volume increases of European flours from two crop years to the protein content of North American flours with which blends were made (A.A.C.C. baking method).

European samples were averaged separately. The average protein content of the two crop years is the same, 9.1 percent. Clearly the 1965 samples (which graded lower and gave some indication of sprout damage) gave larger responses on the average than the 1964 samples; but the effect of protein level of the supplementing flour, as shown by the slopes of the lines, is about equally strong for both sets.

The significance of dividing the samples on a crop year basis can be questioned. However, the average results for the two years did suggest that in the A.A.C.C. baking test the loaf response to a blending flour is larger the poorer the base flour. Figure 3 shows how this works out for the individual

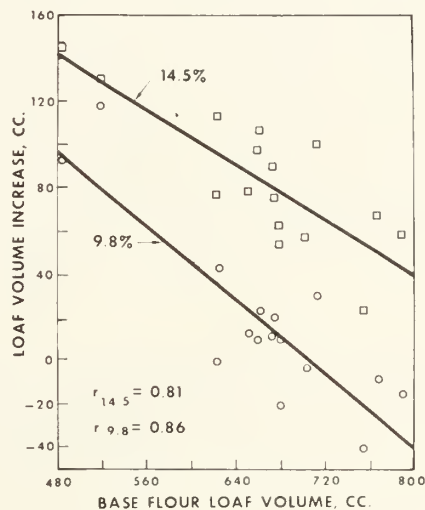


Figure 3.--Scatter diagrams, loaf volume increase of blends over European base flours, for the lowest and highest protein North American blending flours (A.A.C.C. baking method).

European base flours combined with the lowest- and highest-protein blending flours. Increase in loaf volume is plotted against the loaf volume of the European base flours. Despite the appreciable scatter of points, a strong trend is still apparent for the poorer flours to be improved more than the better flours. This held true for all the blending flours; correlation coefficients ranged from 0.76 to 0.87.

Discussion.--In reviewing all the results of the study there are a number of points that call for further investigations, now that some information is available as a base from which to project. Care was taken to composite winter wheats from several sources. Nevertheless it would certainly seem pertinent to

inquire whether other winter wheats equal in performance those used in this study, especially the highest-protein one. Perhaps some would say that the highest-protein winter wheat used here gave unusually good results compared with the spring wheats. Such an opinion is countered by the loaf volume of that winter wheat flour, which was 200 cc. less than that of the spring wheats. Perhaps some investigation ought to be made to see whether particular types of winter wheat that do not give good loaf volumes themselves are still quite useful in "stabilizing" or strengthening weak flours of the European types.

Also, since factors other than total protein content are so clearly involved in the responses, some attempt should be made to identify them. Sprout damage or α -amylase content, as indicated by the Hagberg falling number, is one possibility. The falling number values of the North American winter wheats are definitely higher than those of the spring and European wheats; and this might be related to the improving effect of the winter wheat flours even at low protein levels. However, examination of the values for the European wheats provides little support for this idea; there are some very low values but they do not seem to correlate particularly well with improvements in baking performance.

Another point is the question of blending proportions. In the French baking method especially, the doughs often seemed too strong or tough. Perhaps if only 10% of the North American wheat flours had been used, the relationship among them would have been the same as found by the A.A.C.C. and German baking tests. In contrast, the physical dough tests do not seem especially sensitive to the inclusion of 25 percent of a strong flour in a blend with a weak flour--not nearly as sensitive as the baking tests. The instruments do not seem to be measuring quite the right properties of the doughs.

I have already given the summarization of results and the conclusions they lead to in three different forms. Rather than repeat them again in conclusion, it seems better to repeat a thought from the introduction--that the value of U.S. wheats in supplementing European wheats is worth a periodic reexamination.

SUPPRESSION OF EXCESS ALPHA-AMYLASE IN SPROUT-DAMAGED WHEATS

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As many of you know, the wheat growers of the Pacific Northwest experienced a wet harvest in 1968. Part of the crop was sprout-damaged, but before this was discovered some damaged wheat had been shipped to Japan, milled into flour, and used to make noodles and sponge cake. Apparently much of this sprout-damage was incipient or invisible. Only when the wheat was milled into flour did the problem become apparent. When the flour was used to make Japanese-style noodles, the thin strips stretched and broke while hanging over bamboo poles to dry. Sponge cakes made from sprout-damaged flours collapsed during baking.

About 40 percent of the total wheat flour consumption in Japan is in the form of noodles. Soft white wheats grown in the Pacific Northwest are preferred for this product. While sponge cakes are not a major food item in Japan (6 percent of the flour consumption), their production was at a peak in the late fall of 1968 in preparation for the holiday market, when the sprout-damaged wheats appeared.

Thus the problem was a serious one and resulted in considerable loss of export business in addition to the settlement for damages made by our government, exporters, and growers.

Alpha-amylase is considered to be the enzyme responsible for most of the poor properties associated with sprout-damaged wheat. Our interest in this problem was stimulated by the observation that some naturally occurring phospholipids could inhibit alpha-amylase activity in test tube experiments.

Dr. James Pence of our laboratory was reading the progress report on these studies about the same time he was reading about the sprout-damaged wheat problem in the Japanese market. He wondered if the findings of this basic research might hold a solution to the technological problem. Since then we have been working on this problem and have found that our hoped-for simple solution has become an entree into a rather complex problem.

We began our studies with the noodle problem since noodles are high in wheat usage, and we limited our studies to dried noodles, which are processed like spaghetti in this country. The Japanese also have other noodle products that are cooked soon after the dough is made. These cooked products have some of the problems related to high amylase activity during the early stages of the cooking process. However, since the raw doughs are not dried, it was not possible to anticipate the difficulty that occurred last year, now popularly called the "droopy" noodle problem.

Figure 1 shows the stiff noodle dough after the first sheeting; it was mixed in the small bowl of the Farinograph using the

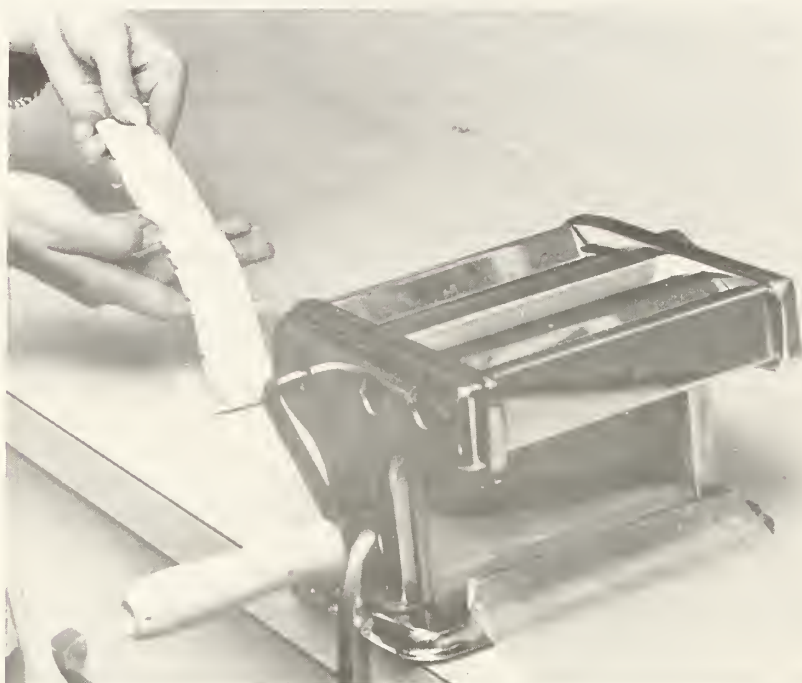


Figure 1.--Noodle dough after first sheeting.

sensitivity setting for the large bowl. The Japanese use a mixer similar to that used in macaroni processing to wet the flour, and after the water is absorbed, they sheet the wet particles through rollers to form the dough. We accomplish the first stage on the Farinograph and then follow the Japanese procedure.

Figure 2 shows the dough being sheeted again. This sheeting is repeated with adjustment of the sheeting rollers until the desired thickness is achieved. The noodle machine shown was made in Italy and can be purchased in San Francisco's Chinatown, but the principle of sheeting and cutting the noodles is the same as that used in Japan.



Figure 2.--Sheeting noodle dough.

Figure 3 shows the dough being cut into thin strands; dough made with sound flour cuts cleanly. The strands hang straight and are separated from each other. Figure 4 shows the cutting problem that occurs with sprouted wheat; the strands stick to the cutting blades, causing curling and rough edges.

Figure 5 shows two sets of noodles hanging to dry. We used a dough fermentation cabinet to achieve a warm, humid atmosphere for slow drying. The sample on the left is made from sound wheat flour; that on the right from sprouted wheat, causing the strands to curl and stick together. Figure 6 shows what happened a few minutes later. The sprout-damaged wheat produced noodles that stretched to the breaking point in the warm, humid atmosphere. These are "droopy" noodles.

When we started the experimental studies last spring, we contacted Mr. Ralph McEwen of the Oregon Wheat Commission for information about and samples of the troublesome wheat. His



Figure 3.--Cutting noodles made from sound flour.



Figure 4.--Cutting noodles made from sprout-damaged wheat flour.



Figure 5.--Noodles hanging to dry. Set on left from sound flour. Set on right from sprout-damaged wheat flour.

organization and the Western Wheat Associates were most helpful in supplying information on Japanese noodle-making and some sprout-damaged wheat. However, by that time, none of the exported wheat that caused problems in Japan was available. We then proceeded to reproduce the problem in two ways: We added flour from commercially malted wheat to sound flour, and we also sprouted our own wheat in the laboratory.

Table 1 shows some of the changes occurring when malted wheat flour is used to achieve high alpha-amylase levels. The wheat used is extensively sprouted to get as high an amylase level as possible. The amylograph peak viscosity and falling number data shown are used because these are tests included in flour specifications in the export market. Malted wheat flour levels of 0.2 and 1.0 percent caused considerable lowering of the hot paste viscosity and, therefore, the falling number value. This value was

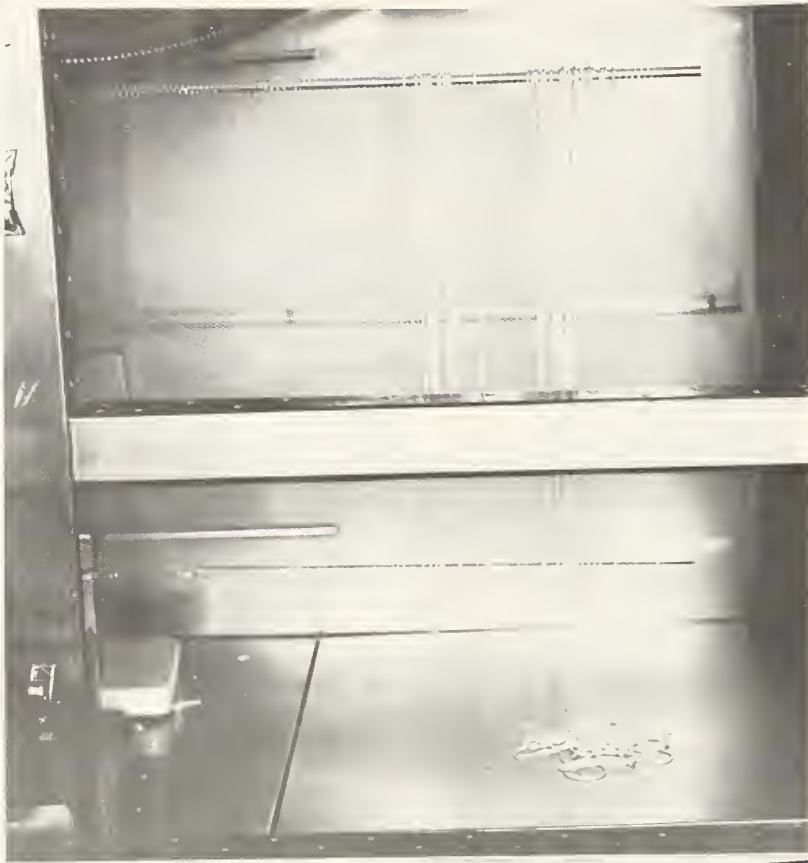


Figure 6.--Noodles from sprout-damaged wheat flour stretched and broken ("droopy").

Table 1.--Effects of malted wheat flour on certain flour properties			
Malted wheat flour level	Amylograph peak viscosity ^{1/}	Falling number	Noodle properties
<u>Pct.</u>	<u>B.U.</u>	<u>Sec.</u>	
0	620	350	good
0.2	220	216	
1.0	105	129	soft
3.0		77	sticky
5.0		65	sticky, break (droopy)
100		60	

^{1/} 85 g. flour, 460 ml. distilled water, 700 cm.-g. head; repeated later using 65 g. flour and peak viscosities of 540, 150, 60 B.U. for same levels of malted wheat flour.

reduced almost to its minimum when 3 percent or 5 percent malted wheat flour was present. The falling number for 100-percent malted wheat flour is included to point out the lowest value possible. In this test a flour suspension is heated (with stirring) for 59 seconds in a water bath. In the next second a micro-switch is activated by a plunger as it falls freely through the hot paste; the length of time it takes to fall is dependent on the viscosity of the cooked paste. Because of extremely high amylase activity of malted wheat flour, the paste is quickly liquefied, and the plunger falls to the bottom of the test-tube immediately. The falling number values then begin with a minimum of 60 in the test.

While 1-percent malted wheat flour indicated considerable alpha-amylase activity toward gelatinized starch, 3 percent was necessary to produce sticky noodle dough, and 5 percent to cause the noodles to break during hanging. These higher levels probably are necessary because the only readily available substrate for the enzyme in raw dough is damaged starch produced during milling and malting. We started the enzyme suppression studies with these malted wheat flour blends but later decided we wanted a flour system more closely resembling rain-damaged wheat.

We sprouted wheat in the laboratory by simulating a wet harvest in warm weather. Table 2 shows some of the results obtained with flours milled from two of the germinated samples, chosen for further work because they represented two borderline levels of sprout-damage. Even though no visible sprouts showed on one sample, the decrease in peak viscosity and falling number from that of the ungerminated control indicates considerable change related to high alpha-amylase activity. The SKB (Sandstedt-Kneen-Blish) value shown is another measure of alpha-amylase activity often used in malting and enzyme studies. This test (1) measures the ability of a 0.5 percent salt-extract of flour to digest a soluble dextrin preparation at 30°C. In the standard procedure, a sound flour indicates too little alpha-amylase activity to measure. Our laboratory-germinated wheat gave values of 0.33 and 0.83, which are low when compared with those of malted wheat flour (60 to 67 SKB units). However, both samples contained enough alpha-amylase activity to make droopy noodles, and they were used in experiments with phospholipids and other additives in attempts to suppress enzyme activity.

Several additives that influenced noodle dough behavior are shown below. The first three, salt, trisodium phosphate, and alkaline water are substances commonly used in Japanese noodles, either separately or in combination (2, 3). This past summer we learned from visiting representatives of Japanese food industries that they have considerable variation in noodle formulations. They may use as much as 3.5 percent salt in doughs for strengthening.

NOODLE DOUGH IMPROVERS

Now used in Japan:

Salt	1.0 to 3.5 pct.
Trisodium phosphate	pH 7.0 to 7.5
Alkaline water	3.5° Baumé

Experimental additives:

EDTA
Sodium phytate
Phospholipid
Phospholipid plus Fe⁺⁺

The Japanese want their noodles neutral or slightly alkaline (7-7.5 pH), and above the pH of a flour-water mix (pH 6.0). To raise the pH, they use trisodium phosphate or alkaline water. Both additives tend to make dough from sprout-damaged wheat flours less sticky. We found that addition of EDTA at 100 p.p.m. proved to be quite effective in reducing stickiness; it was more effective at high pH in the presence of phosphate. Sodium phytate is also effective in decreasing dough stickiness. These additives bind metal ions strongly, particularly calcium, which is considered necessary for alpha-amylase stability. We believe removing calcium from the system lowers amylase activity, but it has not been established. Some additives may also significantly affect proteins which we hope to investigate later.

This then brings us to the phospholipid compounds. Calcium-binding is a property of the phospholipids too, but we believe they act in a different way to inhibit amylase activity. First, the phospholipid compounds occur naturally in wheat, soybeans, egg yolk, beef brains, and a wide variety of lipid-containing foods. Some bind calcium and other metal ions, but their distinctive feature in this work is that the phospholipid-metal complex can, in turn, combine with some soluble proteins and enzymes to make them insoluble and to suppress their activity.

Phospholipids are like simple fats except that one of the fatty acid groups is replaced by a phosphate ester. Besides phosphate, this ester contains an amino acid or a sugar or a more complex compound. The nature of the compound attached to the phosphate determines the ionic properties of each phospholipid. In the basic studies on phospholipids from wheat and other sources, several species were found that would bind soluble wheat proteins when divalent metal ions such as calcium, magnesium, iron or nickel were present (4). The array of proteins bound by this complex varied with the choice of phospholipid and metal. This variation is thought to be due to the spatial arrangement of

Table 2.--Some changes occurring in flour from slightly sprouted wheat

Flour sample	Amylograph peak viscosity	1/ B.U.	Falling number	SKB units	1/ Noodle properties
Gaines SW flour, sound control	(1,200)		570	2/	good
Lab-germinated:					
No visible sprouts	355		200	0.33	droopy
Visible sprouts	--		100	0.83	droopy
Malted wheat flour	--		60	60-67	

1/ 100 g. flour, 460 ml. water, 700 cm.-g. measuring head.

2/ Too small to measure.

the amino acids in the protein and to the size of the metal ion. In other words, consider the metal as a coupling, joining the phospholipid and protein.

Of particular application to this project were our recent findings that certain enzymes were among the soluble proteins bound. Alpha-amylase was bound effectively by phosphatidyl serine and nickel and by triphosphoinositide alone and in combination with nickel, magnesium or iron. We have used the triphosphoinositide in noodle doughs and noted some improvement in handling properties but hesitate just yet to make conclusive statements about its success for two reasons: (1) the compound is difficult to prepare so our supply is limited for extensive study of its effect in doughs, and (2) our noodle-making techniques are not yet developed to the point where results can be translated into a practical system in Japan.

A more concrete example of the effectiveness of this compound is that summarized from the test tube experiments. The amylase activity of a malted wheat flour extract was reduced one-third to one-half by triphosphoinositide depending on the metal present. The iron-phospholipid complex was especially effective at pH 8.

This combination was then used to study the suppression of alpha-amylase in the sprouted-wheat samples (table 3). The first

Table 3.--Effect of phospholipid on suppression of alpha-amylase
SKB units

Flour sample	No treatment	Phospholipid + Fe ⁺⁺	
		Unbuffered	Treated at pH 8
Lab-germinated:			
No visible sprouts	0.33	0.11	0.08
Visible sprouts	.83	.65	.65

sample shown with an SKB value of 0.33 is that described earlier which had a falling number of 200 and made droopy noodles. The SKB value was reduced to one-third of the starting value with the phospholipid-iron complex. The visibly sprouted sample with the higher SKB (0.83 units) showed a smaller percentage of decrease but almost the same actual decrease in terms of SKB units. These samples were treated with the same quantity of phospholipid (approximately 0.6 percent).

Addition of higher levels of phospholipid may effect further inhibition of amylase. As more of the compound becomes available, studies will be undertaken on necessary levels and conditions for

optimum effectiveness of the inhibitor. The phospholipid for these experiments was prepared from beef brain extracts because it was the most convenient source of a concentrated amount of tri-phosphoinositides. Naturally bound metals were removed by a demineralizing resin. This step is necessary to make the phospholipid effective.

Recently, we prepared some demineralized lecithin from a commercial soybean source. Mixing with this phospholipid also improved noodle-dough properties. Work is continuing on the elucidation of these effects.

Besides inhibiting alpha-amylase, some of the phospholipid-metal combinations inhibited wheat lipoxidase activity. Lipoxidase activity is not a problem in these white wheats but sometimes is in durum products. Application of our findings to pasta production problems might be fruitful.

We are now turning our attention to the ability of these complexes to bind proteases in sprout-damaged wheats. High protease levels may also be implicated in the droopy noodle problem. Some of the noodles stretch considerably before breaking, causing us to wonder if gluten proteins might be affected. In some of the noodle doughs we have been able to eliminate the stickiness associated with high-amylase activity, but we cannot always eliminate the stretchy quality. Recently a method for determining protease by gel electrophoresis was published by some Canadian workers (5). Application of this sensitive and easy-to-use method to our studies showed considerably more proteases in malted wheat flour than in sound flour (fig. 7).

The direction of migration in the gel is from right to left. The small band on the top line indicates protease from sound wheat. The large band (or spot) on the bottom is several overlapping protease bands from malted wheat flour. In this same test, lab-sprouted wheat gave more individual bands than did the sound flour, indicating not only more protease but more than one enzyme. A publication on this aspect will be prepared shortly.

High protease levels in malted wheat flour have been studied in the past in regard to bread dough systems but have not been a significant problem. It may be that in such a simple system as these noodles represent, protease activity is more important. The noodles are made primarily from soft wheat flour; their proteins may differ from bread wheats in susceptibility to enzymes. The phospholipid-metal complex may prove to be a suitable agent for inactivating protease as well as amylase.



Figure 7.--Pattern of wheat protease components from sound and malted wheat flours observed by gel electrophoresis.

Another promising aspect of the phospholipid-metal complexing system is its acceptability as a food additive, since phospholipids are naturally-occurring compounds. Also in pure form they would not change the basic eating quality of these noodles, an important factor in such a traditional and relatively simple food.

Hopefully, 1968 wet harvest conditions in the Pacific Northwest will not occur again, but completely dry harvests are too much to expect every year. While our possible solution for the problem would offer a stop-gap measure in crisis situations, a more permanent remedy should come from the Wheat Quality Survey launched this year by the various Pacific Northwest wheat groups through their Grain Standards and Quality Committee.

I'm sure you know that sprout damage isn't an isolated problem. There have also been years when the durum wheat crop has suffered from adverse weather. Since the Japanese noodles are processed similarly to spaghetti, the findings of our study should be applicable to problems of pasta production arising from wet harvests as well as from lipoxidase, mentioned earlier.

Also, because wet harvests are a perennial problem in Europe, future findings may help our neighbors abroad.

As a dividend from a project such as this, we hope to develop some knowledge of and experience with the various products the Japanese make with American wheats. This information will be helpful to the plant breeder and other people who deal with the technological problems important to American wheat growers interested in supplying this market.

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HIGH PROTEIN BREADS

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The increasing consumption of wheat-based foods in the developing nations of the world presents the brightest outlook for increased utilization of wheat.

Several concurrent programs and developments around the world tend to cloud our vision of what this increased consumption will actually mean to U.S. wheat producers and processors. A brief coverage of some of these developments seems pertinent to this conference. Before that can be adequately undertaken, definitions of the breadstuffs under consideration must be given.

The familiar American white pan bread has been of minor importance in the rest of the world until very recently. With our wheat export and marketing programs, this type of bread has been readily accepted in Japan and other rice eating areas and in the urban centers of most developing nations.

Although statistics are not available on consumption of bread by types, it is felt that consumption of French style bread still far exceeds white pan bread outside the United States. This bread is generally made from 80 to 85 percent extraction flour.

Another important bread of the world might be called "Arab" bread because it is generally consumed throughout the Moslem areas of North Africa and the Middle East. This bread is a dense, moist, coarse-textured, thick-crust bread made from 90 to 95 percent extraction wheat flour which may or may not be blended with rye or barley flour.

The fourth major bread type is the unleavened fried bread called "chappaties" of India and Pakistan.

Other wheat foods such as pasta products, couscous, pastries, and gruels cannot be described as bread but are important to consider within the context of this discussion.

At the risk of redundancy, American and French style breads are being consumed in increasing quantities throughout the developing world. Not only have these products been accepted in Asia and South America by former rice and corn eaters, but they have become the prestige or status food. While these consumption trends appear to be good for American wheat and flour exports, they present real problems to our developing nation customers.

First of all, where breadstuffs have been the main part of the diet, there is a desire to build more nutrition, primarily through improved protein quality, into the wheat-based foods in the form in which they are presently consumed. The shift from products made from high extraction flours to white bread from lower extraction flour accentuates this problem as the protein nutritional quality decreases with a lowering in extraction rate.

Secondly, the developing nations want to lessen their dependence on outside sources for their food supply to save foreign exchange and to stimulate local agriculture and industries and thereby provide employment.

This combination of urgent need for better nutrition and nationalistic goals for stimulating agriculture and industry has led to a flurry of scientific and pseudoscientific research on

the effects of addition of nonwheat proteins and carbohydrates on nutritional values, functional properties, and acceptability of wheat based foods.

The extreme example of such research is sponsored by the Food and Agriculture Organization of the United Nations at the Institute for Cereals, Flour, and Bread at Wageningen in the Netherlands to develop a "composite flour" from noncereal tropical crops from which high quality bakery goods comparable or superior to those made of wheat flour could be made. This widely reported work has studied the effect of raw materials and mixing. The best of many combinations tried was composed of a flour made of 80 parts cassava flour and 20 parts soy flour. The batter type dough is made of a mixture of flour, 70 to 80 percent water, 1 percent glyceryl monostearate, 2 percent yeast, and 4 percent sugar by mixing in a planetary mixer. The resultant loaf is a very poor quality white pan bread, at best.

There is much more interest around the world in extending wheat flour with nonwheat starches and proteins than in complete replacement. In wartime, wheat flour has been traditionally extended by increased extraction rates or adding other cereal flours. Currently several governments rigidly control extraction rates and establish the amount of indigenous flours which must be added to wheat flour. For example, in Pakistan the amount of grain sorghum which must be blended with wheat for commercial milling is controlled by regulation. Sometimes the blend contains as much as 10 percent sorghum. Similarly in Paraguay and Brazil, cassava flour must be added to wheat flour.

From the nutritional standpoint, research is under way in all parts of the world on the addition of proteins to wheat flour from all practical and many impractical protein sources. It is axiomatic that the addition of nonfunctional nutrient additives to breadstuff formulations will change organoleptic properties such as flavor, color, texture, appearance, aroma, and volume.

An extensive research effort on high protein breads at the Food and Feed Grain Institute of Kansas State University is being sponsored by the Agency for International Development and several industrial organizations. The several projects deal with nutritional improvement of chappatis, couscous, Arab bread and white pan bread. Protein resource materials under study include various soy protein products, cottonseed flour, peanut flour, chickpea flour, horsebean flour, sesame flour, high-lysine corn flour, various high protein fractions from wheat, fish-protein concentrate, food-grade yeast, nonfat milk solids, and synthetic amino acids.

Our approach is to determine the effect of different levels of these additives upon the chemical and physical functional properties of dough and upon the organoleptic acceptability of the wheat food product. In addition, the nutritional value of the finished foods is being determined. Inherent in such a program are studies on the effect of changes in nonwheat protein form, processing conditions, and other ingredients which might be used to make the nonwheat protein more functional. The evaluation of nonfat milk solids and necessary formula and process modifications before milk protein was widely accepted in white pan bread serves as an example of the need for such research.

A great deal of research has been carried out in this country on the use of soy protein in the form of soy flour, grits, soy protein concentrate and isolates in white pan bread. It has been found that the bread baking potentialities of soy products are improved by using a soy grit rather than a finely ground flour, using an increased oxidant level, adding about 2 percent lecithin to the formula, and using soy products with a minimum heat treatment (necessary for destruction of "antigrowth" factors in the raw soy material). In spite of this research effort, soy proteins are normally not used at levels over 3 percent because of deleterious effects on bread quality. While the nutritional value of bread would be improved somewhat at that level, it would be necessary to add 7.5 to 15 percent soy flour or grits to achieve a meaningful improvement in diets composed primarily of bread.

Research conducted by Kirleis and Robinson (1) studied the effect of the particle size of 70 percent soy concentrate, oxidant level, and type of baking process when substituting the soy for 7.5 and 15 percent of the flour on the farinograph, extensograph, and baking properties of bread. Specific loaf volumes for all soy concentrate-wheat-flour blends made by straight, no-time, and continuous-dough methods were significantly lower than the average specific volume of the basic wheat flour formula. For each method, the 7.5-percent level of soy concentrates had a less deleterious effect on bread quality than did the 15-percent level. Bread made with the coarse granulation concentrate had better color and crumb softness than did the medium or fine grinds. Bread made by the continuous-dough method was least affected by addition of soy concentrate; it had better crumb grain and color and larger loaf specific volume than did the straight or no-time dough method. This confirms the report by the Institute at Wageningen and by the Arkady Bakeries in England that best results are obtained with "composite flours" if high speed mixing is used.

Pomeranz along with several of his students at Kansas State University have carried out an elucidating series of studies into the role of lipids in bread quality. These studies brought into

focus the importance of a glycolipid component of wheat flour. Adding commercially available sucrose esters which are chemically similar to the natural wheat glycolipids had no beneficial effect on the functional properties of gluten present in wheat flour. Pomeranz, Shogren and Finney (2, 3) did discover the rather amazing fact that the addition of sucrose esters counteracted the deleterious effect of up to 16 percent soy flour concentrate or isolate on loaf volume, crumb grain, and softness. The sucrose esters did indeed render the soy proteins functional in bread-making.

This finding was quickly followed with a series of bakes made with 8 parts (per hundred parts wheat flour) of defatted cottonseed flour, fish protein concentrate, defatted wheat germ, air-fractionated protein-rich wheat flour, food grade Torula yeast, nonfat milk solids, expeller-extracted sesame seed flour, or wheat gluten. All the protein-rich additives substantially lowered loaf volume and impaired crumb grain. Loaf volumes were increased and crumb grain was improved by adding 1 to 6 parts sucrose tallowate.

Robinson, Phillips and Kirleis (4) have recently studied the effect of adding the sucrose esters to soy-containing breads made by the continuous mix method. Without the sucrose esters, the quality of bread as measured by specific loaf volume with 7.5- and 15-percent soy-protein concentrate was poorer than that of the all wheat flour control. With the addition of 3 percent sucrose ester, the quality of the 15-percent soy-protein concentrate bread was equal to that of the control and the 7.5-percent soy bread was superior to that of the wheat flour control.

The development of high lysine corn has led to strong interest, particularly in South America, in whether flour from high lysine corn could be used as a partial replacement for wheat flour in wheat breads. High lysine corn flours from several genetic backgrounds were available from milling studies conducted at Kansas State by E. P. Farrell. In research reported by Robinson, Farrell, Deyoe, and Hoover (5) corn flours were added in 5-percent increments up to 20 percent of both medium- and high-protein level hard red winter wheat flours. The effect of these corn flour additions on physical dough properties, chemical composition of blends, and baking properties was evaluated. Specifically, corn flours from three high lysine corn samples and normal corn were used.

Nutritionally, none of the corn flours appreciably changed the lysine content of corn-wheat flour blend even when added at the 20-percent level. High protein fractions from air-classified corn flour did effectively improve the lysine content of wheat flour blends.

The physical dough properties of blends of wheat flour with all the corn flours were quite similar, with high lysine corn flours being perhaps slightly better than the regular corn flour. In baking tests, it appears that highly acceptable bread could be made using up to 10 percent of any of the corn flours, while the quality was lowered if more than this level was used. Higher protein wheat flour can definitely "carry" more nonwheat flour than can medium protein wheat flour.

This paper has by necessity been limited to reporting some isolated studies taken out of context of our overall research program at Kansas State University. We are actually doing more work on Arab bread, couscous, and chappatis than on white bread. These studies were selected to illustrate several points that will play important roles in wheat utilization in the future, namely, (1) breadstuffs that will contain nonwheat flours or nonwheat protein in the formula will be widely consumed; (2) high protein wheat flour with good baking properties will likely be desired for composite flours; (3) to maintain or improve the nutritional value of breadstuffs, a policy should be urged to require the addition of protein whenever a high carbohydrate flour or starch is added to wheat flour so that at least the same protein level of the basic wheat flour is maintained; (4) with one or two exceptions, nonwheat flours or protein products are not now available in sufficient quantities and consistent quality to permit wide usage in composite flours. This availability of basic nonwheat raw materials will prove to be the biggest deterrent to the development of wider usage of composite flours in breadstuffs.

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REACTION OF STORED-PRODUCT INSECTS TO SOME NEWLY DEVELOPED WHOLE WHEAT PRODUCTS

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Western Utilization Research and Development Division, ARS, at Albany, Calif., in the continuing search for new uses of wheat, has developed several promising wheat products. The marketing of these new products is of considerable interest in that it will create a new outlet for wheat by making available additional nutritious foods that may be processed into ready-to-eat products. However, a knowledge of the relative resistance or attractance of these products to stored-product insects is necessary to effectively plan and develop their export market potential. This paper reports results of tests conducted to determine the degree of attractiveness of these wheat products to two species of stored-product insects--the rice weevil, Sitophilus oryzae (L.) and the red flour beetle, Tribolium castaneum (Herbst).

Materials and Methods

Test products.--The newly developed products were two pearled wheats and three WURLD wheats developed from Gaines wheat. Bulgur, Gaines wheat, and white flour prepared from Gaines wheat were used as comparison controls. A description of all materials and their moisture content 2 weeks after receipt at the laboratory are given in table 1. The two pearled wheats were somewhat soft and covered with a light coating of flour with traces of bran still on the kernels. The WURLD wheats were similar to bulgur but were much lighter in color as a result of the chemical peeling of the bran. The kernels also appeared larger than bulgur kernels with some markedly expanded and flattened. The scarified WURLD wheat had a light color but appeared more of the texture of whole bulgur than did the other WURLD wheats. The WURLD wheats were developed to satisfy the demand of those who prefer a whiter product, more like rice. The process of their preparation has been described by Morgan and coworkers (1964) (1). The bulgur comparison control was obtained from a Kansas source and was prepared from hard red winter wheat. The bulgur had much of the bran removed and the endosperm was more shiny and translucent than the endosperm of the unprocessed wheat kernel; otherwise it was similar to raw wheat.

Table 1.--Moisture determinations of whole wheat products developed by WURDD (by the oven method)

Test materials	Moisture content
	<u>Percent</u>
Experimental products:	
WURLD wheat--parboiled, lye-peeled, acetic-acid neutralized	10.55
WURLD wheat--parboiled, lye-peeled, benzoic-acid neutralized	10.21
WURLD wheat--scarified	11.95
Pearled wheat--light abrasion to remove outer bran layers, 88-percent recovery	10.75
Pearled wheat--heavy abrasion to remove the majority of the bran, 73-percent recovery	9.80
Check or control materials:	
Gaines variety wheat--whole and untreated	9.92
White flour--prepared from Gaines variety wheat	9.43
Bulgur--cracked and unsized	12.82

Test insects.--The rice weevil and red flour beetle were from strains regularly maintained by the Mid-West Grain Insects Investigations, Manhattan, Kans., and were selected for their importance as stored grain pests.

The rice weevil is considered one of the most destructive insect pests of stored whole grain. It is a small, reddish brown to nearly black beetle about 1/8-inch long with four light reddish or yellowish spots on its back. The head is prolonged into a long slender snout at the end of which is a pair of strong mandibles or jaws. The female bores a small hole in the kernel into which she lays an egg and then covers and seals the opening with a gelatinous plug. The egg hatches into a legless larva which completes its growth within the grain. When fully grown, the larva transforms to the pupal stage and then to the adult weevil which

bores its way out of the kernel. Under ideal conditions, the development time from egg to adult is approximately 30 days. Adults live from 4 to 5 months during which time the females lay about 300 to 400 eggs.

The red flour beetle is one of the important pests of ground cereal products, with an average life span of 1 year in the adult stage. The female lays about 450 small, white eggs loosely in the food material in which the insects are living. The eggs are covered with a sticky secretion and soon become covered with bits of the material they are in, making them hard to find. The sticky secretion also lets them readily adhere to the sides of sacks, boxes, and other containers and, as a result, they are unknowingly spread from place to place. In 5 to 12 days the eggs hatch into small wormlike larvae, which when full grown are about 3/16 inch in length, white, and tinged with yellow. The grown larvae eventually change to pupae from which the adult beetles emerge. The time of development from egg to adult under ideal conditions is approximately 40 days.

Distribution studies.--A series of tests was run for each of the two insects used in the study. Insect distribution among the wheat samples was studied in two types of test chambers. One type chamber was a 2-foot by 2-foot by 6-inch frame (fig. 1). Five samples of each of the eight test materials were placed (one sample per box) in open plastic boxes 1-3/4 by 1-3/4 by 5/8 inches deep. A set of 40 sample boxes was randomly placed in each of five exposure chambers. About 800 insects (both male and female) were released in each chamber. A sheet of 6-mil plastic was tightly drawn over the tops of the chambers. At the end of 7 days, the chambers were opened, the plastic boxes quickly capped to contain their infestation, and all insects free in each chamber and in each plastic box were removed and counted. The test materials were retained in a rearing room for progeny development.

The other type of distribution test chamber was a glass covered frame measuring 13-1/2 by 8-1/2 by 1-1/2 inches (fig. 2). Four samples of each of the test materials, except the 88-percent recovery pearled wheat and the white flour, were exposed to the insects in a thin layer in boxes measuring 1-3/4 by 1-3/4 by 3/16 inches. The 88-percent recovery pearled wheat was omitted so that only one pearled wheat sample would be present for selection by the rice weevil. The flour was omitted because the rice weevil cannot develop in it. A set of 24 samples was placed in each chamber. Ten rice weevils or red flour beetles were released in each chamber. The

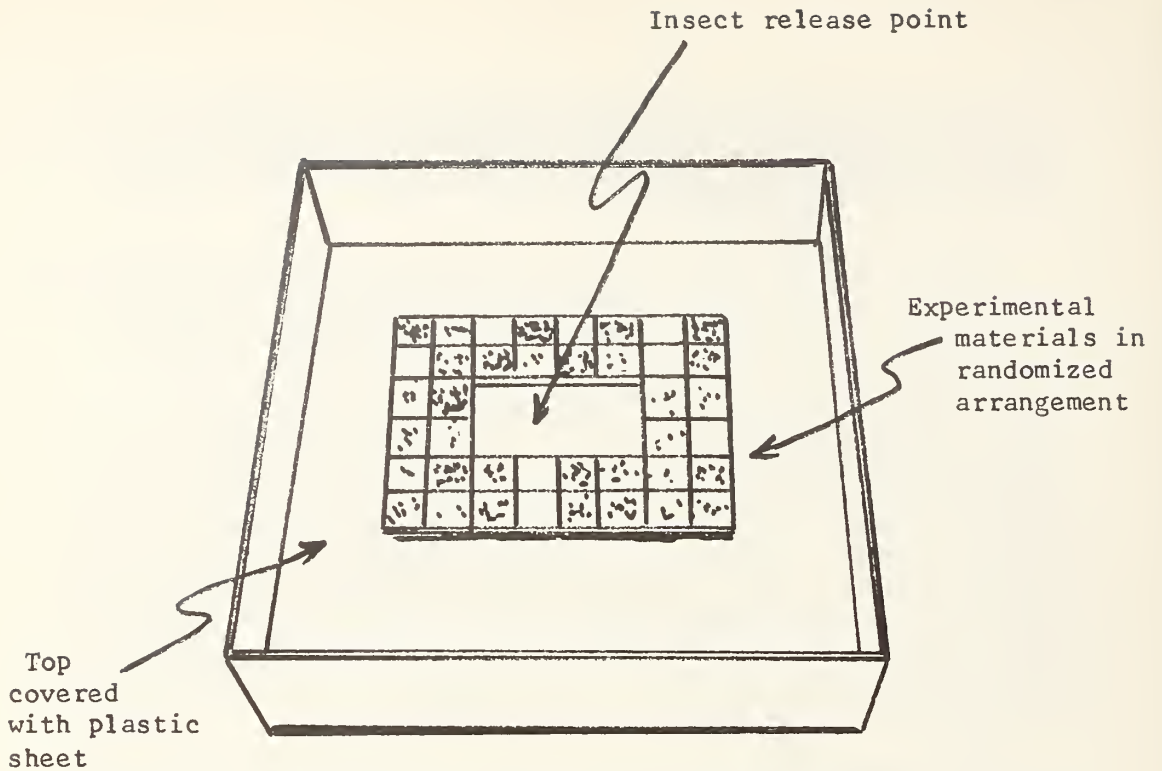


Figure 1.--Large exposure chamber (2 feet x 2 feet x 6 inches) used to expose stored-product insects to wheat products.

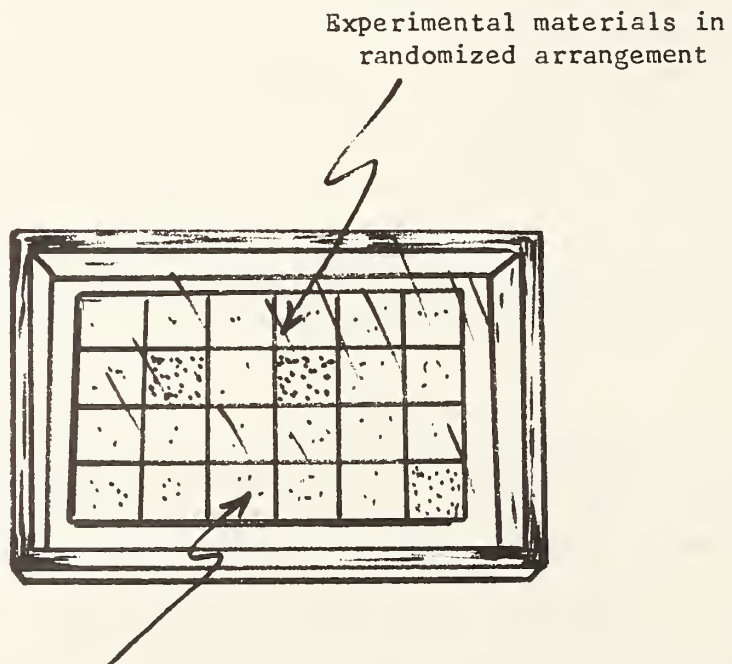


Figure 2.--Small glass-covered exposure chamber (13-1/2 x 8-1/2 x 1-1/2 inches) used to expose stored-product insects to wheat products

chambers were covered with glass plates to allow inspection without disturbance of the insects or the materials. At the end of each 24-hour period for 6 days, the number of insects in each sample was estimated. At the end of 7 days, each chamber was opened, the boxes with their test materials were capped to contain their infestations, and all free insects in the chamber were counted. Insects in each of the boxed samples were then removed and counted, and the boxed material was retained in the rearing room for progeny development.

Direct comparison studies.--From the data of the distribution tests, pairings of the more susceptible and less susceptible materials were made for preference-type repellency studies. A modification of the testing apparatus described by Laudani and Swank (1954) (2) was used (fig. 3). In each test six 1/4-pint samples of each of 2 products were exposed for 24 hours to a dispersal of 500 insects of each species.

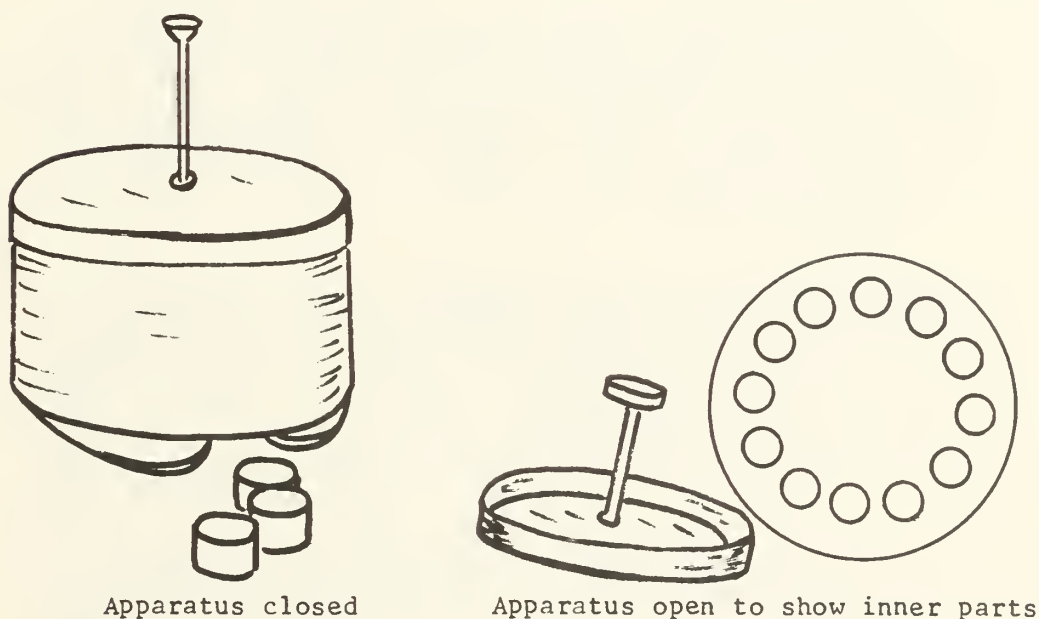


Figure 3.--Apparatus used for conducting free-choice, preference-type repellency tests with pairing of whole wheat products

Results

Rice weevil.--The pearled wheats were more susceptible to the rice weevil than were the WURLD wheats.

In the large chambers about 850 beetles invaded each of the pearled wheat samples. Progeny increase was about 10 times this number. In comparison, the average number of beetles in the WURLD wheat samples was 350 with a progeny increase of two-fold to tenfold. The benzoic-acid neutralized wheat samples were the least susceptible. The whole wheat control sample with 892 weevils was more susceptible than was cracked bulgur (156 insects) or white flour (42 insects). With the exception of flour, the progeny increase was tenfold. The trend of sample-susceptibility in the small chambers was similar to that in the large chambers.

In direct comparison studies, where pairings were made between only two products at a time, the findings of the distribution studies were confirmed. Parboiled, lye-peeled, benzoic-acid neutralized WURLD wheat was less attractive to the rice weevil (40-percent response) than was parboiled, lye-peeled, acetic-acid neutralized WURLD wheat (60-percent response). When the latter was compared with the basic check material, whole Gaines wheat, it attracted only 6.8 percent of the insects. The whole Gaines wheat attracted only 37.7 percent of the insects when compared with the most attractive test material, pearled wheat of light abrasion and 88-percent recovery; it attracted 54.1 percent of the insects when compared with the scarified WURLD wheat, and 58 percent of the insects when compared with whole bulgur.

Red flour beetle.--The pearled wheat samples were more attractive than the WURLD wheat samples to the red flour beetle, as they were to the rice weevil when the beetles were given a choice of all products in the large chambers. About 110 adults were in each of the pearled wheat samples at the end of 7 days and about 3,500 progeny developed in each. Adults and progeny in the WURLD wheats averaged 60 and 11, respectively. Of the controls, white flour had the greatest numbers of adults and progeny, 375 and 1,866, respectively. The whole wheat attracted fewer adults (70) than did the cracked bulgur (130), but the number of progeny in the whole wheat was greater (676 vs. 58). Results of the studies conducted in the glass-covered chambers indicated that the red flour beetle was not attracted and held in any of the materials during the 7-day exposure period. Tests to determine the reason for this reaction are still in progress.

In direct comparison studies, the findings of the distribution studies were confirmed. The parboiled, lye-peeled, acetic-acid neutralized WURLD wheat attracted slightly more insects (53.5-percent response) than did the benzoic-acid neutralized

WURLD wheat (46.5-percent response). When the less attractive material of the pairing, benzoic-acid neutralized WURLD wheat, was compared with the most attractive of the experimental materials in the large chamber test, pearled wheat of 88-percent recovery, it attracted only 16.2 percent of the insects. The pearled wheat of 88-percent recovery attracted 41.9 percent of the insects when compared with pearled wheat of 73-percent recovery; 86.1 percent, with Gaines variety wheat; 71.8 percent, with cracked bulgur; and 68.7 percent, with scarified WURLD wheat.

Discussion

The results of all tests indicated that the experimental materials most consistently attractive to adults of the rice weevil and the red flour beetle were the pearled wheats. These materials also were most attractive for the progeny production.

The parboiled WURLD wheats neutralized with either acetic or benzoic acid were not very attractive to either species of insect. The emergence of rice weevil progeny from the parboiled WURLD wheats neutralized with either acetic or benzoic acid was several days later than the progeny emergence from either the pearled wheats or the Gaines wheat control. The red flour beetle larvae could not develop on these parboiled WURLD wheats.

In the distribution studies, the rice weevil distributed itself throughout the materials starting with the first day and maintained this pattern of distribution throughout the observation period of 7 days. The red flour beetle was not attracted and held in any of the materials during a 7-day observation period but did show a preference for the pearled wheats in which to deposit eggs.

Further study is needed to determine the reaction of other stored-product insects to these materials, especially the effect of different environmental factors on the ability of the materials to attract and support populations of stored-product insects.

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EFFECT OF SALTS ON INSECT RESISTANCE OF CEREAL PRODUCTS

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The existence of a pest is markedly influenced by the physical conditions of the product. Most of the grains show a definite sequence of infestations by taxonomic group of insects from the time the grain is placed in storage until it is milled and manufactured into its various products.

For protection of food grains and their products from insect attack, toxic chemicals are used. They belong to the group of substances known as pesticides. During the last two decades, intensive research on evolving pesticidal chemicals has been carried out. An array of chemicals has been synthesized for use against pests.

The technological progress of this century served as an elixir to the infant pesticide industry of the second world war, with the result that the industry has today grown into a mighty giant by producing a variety of deadly insecticides. These chemicals are not specific to insects alone but exert toxicity to almost all forms of life, thus threatening the very existence of many biological species. The indiscriminate use of pesticides in an attempt to control pests of medical and agricultural importance has created serious public health problems (Carson 1963).

It is a common observation that when stored grain insects are offered a choice of several materials, some of the commodities are found unsuitable for their breeding. The possible means of utilizing this phenomenon is to apply that material on the substrate to be protected. This procedure is based on fundamental principles of ecology, that is, conditioning of the environment. The environment is to be changed in such a way as to make it unfavorable for insect breeding. From time immemorial, many serious attempts have been made to protect grain against insect attack by using foreign substances. Some of the curious early practices were: covering the grain with mineral and herbal protectants, burning various aromatic substances in the storage space, and mixing toxic chemicals like mercury and arsenic with the grain. In the course of time, the old methods gave way to newer methods of storage using food additives and pesticidal grain protectants.

Several workers have tried to achieve an easy method of control of stored-grain pests either by adding or deleting various materials to the substrate to check the breeding of insects. Fraenkel and Blewett (1963) have shown that in the absence of certain vitamins and fats, the development of some stored grain insects is delayed.

Malnutrition as a tool for control of stored grain insects fails from the point of view of human consumption of food materials, because eliminating essential nutritive factors from the foods may cause abnormalities in human metabolism.

Steinhaus and Bell (1953) found the inhibitory effects of streptomycin, terramycin, and penicillin against Sitophilus oryzae (rice weevil) and Tribolium confusum (confused flour beetle) and pointed out the possibilities of using these antibiotics for the control of stored grain insects. But the applicability of these methods is yet to be explored with special reference to permissibility in foods.

Pant and Dang (1965) found that arabinose, rhamnose, galactose, and dulcitol are toxic to T. castaneum (red flour beetle) larvae at 31.25-percent level and sorbose was toxic at 12.5-percent level. The levels of sugars used for killing the insects are quite high and are impracticable from the economic point of view.

The review of earlier work has revealed gaps in our knowledge of an approach to insect control, using chemicals which could be highly toxic to insects and at the same time nutritionally valuable to humans.

Innumerable organic and inorganic salts have been synthesized or occur in nature in the native state. All of them cannot find acceptance in food composition because of inherent chronic or acute toxicities to man and animals. Limited number of salts of sodium, potassium, ammonium, magnesium, aluminum, and calcium could find acceptance in foods, at least in low concentrations. Therefore, the candidate chemicals were selected out of the array for determining their effects on growth and development of stored-product insects (Majumder and Bano, 1964). The toxicological action of the candidate chemicals was exhibited by reduction in population, prolongation in life period, and attenuation of growth (Bano and Majumder, 1965; Majumder and Bano, 1966). Using these criteria, various degrees of toxicity or inhibitory effect of these salts could be observed.

Screening experiments were first conducted on the effect of different salts at comparatively low concentrations on the growth and breeding of T. castaneum in wheat flour.

Materials and Methods

Some of the promising salts (A.R. grade) selected for the studies were: chlorides, carbonates, bicarbonates, sulfates, nitrates, and phosphates of sodium, potassium, calcium, magnesium, ammonium, and aluminum.

The salts were ground to pass 100-mesh and mixed with wheat flour at levels of 0, 10, 100, 1000, 10,000, and 30,000 p.p.m. There were 10 replicates for each treatment. Ten adults of T. castaneum were released in each treatment. The materials were incubated at 26° to 28° C. and 72 to 75 percent relative humidity for 120 days. Observations were recorded on growth and emergence of different stages of insects, and also on external and internal pathological changes in the insect body caused by the salts which proved to be highly toxic. Transverse and longitudinal sections of healthy and diseased larvae were taken.

Results

Of all the salts tested, carbonates, bicarbonates, sulfates, and phosphates of calcium, sodium, potassium, magnesium, and aluminum exhibited toxicity at 10,000 p.p.m. (1-percent level) and 30,000 p.p.m. (3-percent level). The same results were obtained with chlorides of sodium, potassium, calcium, ammonium, and aluminum, but not magnesium. In the case of magnesium chloride, the breeding of insects was enhanced, in other words, magnesium chloride was beneficial for insects. The toxicity of all the above salts was indicated by reduced total population, prolonged period of development and reduction in average weights. This could be caused by the salt imbalance in the insect's body system.

Table 1 shows that all the calcium salts tested at 10 p.p.m. (0.001-percent level) and above in the growth medium resulted in inhibition of growth of T. castaneum. The significant reduction in weights at lower levels and mortality at 30,000 p.p.m. (3-percent level) indicated that calcium phosphate has a growth inhibitory effect on insects greater than that of any of the other salts.

The results indicate that all calcium salts do not bring about total growth inhibition in insects, which presumably means it is not only the calcium ion which is toxic but the compounding anion also has a major share in inducing growth inhibition.

These observations warranted further study on the effect of calcium phosphate on the growth and development of some common stored grain pests.

Therefore, an attempt was made to determine the effect of changing the pH of flour treated with monocalcium, dicalcium, and tricalcium phosphate by using sodium carbonate and buffer salts (B.D.H.). The results in general showed accentuation of the toxicity of tricalcium phosphate to T. castaneum with

Table 1.--Screening of salts for their effect on *Tribolium castaneum*

Concentrations in p.p.m.	Percent inhibition ^{1/}					
	Chloride	Carbonate	Bicarbonate	Sulfate	Nitrate	Phosphate
SODIUM						
0	0	0	0	0	0	0
10	24.7	39.8	47.3	22.6	31.2	33.3
100	32.3	47.3	48.4	35.5	36.6	36.6
1,000	41.4	51.6	55.1	46.2	39.8	39.8
10,000	47.3	52.7	60.2	49.5	47.3	43.0
30,000	55.9	65.5	64.5	52.7	53.8	51.6
POTASSIUM						
0	0	0	0	0	0	0
10	39.8	40.0	30.7	28.4	25.0	30.7
100	42.0	42.0	40.9	28.4	28.4	37.5
1,000	42.0	52.0	44.3	32.9	30.7	39.8
10,000	42.0	60.0	55.7	38.1	36.4	43.2
30,000	44.3	65.0	63.6	40.9	45.5	43.2
CALCIUM						
0	0	0	0	0	0	0
10	39.8	42.0	38.7	31.2	35.5	25.0
100	41.9	48.0	41.9	34.4	45.2	28.8
1,000	55.9	48.0	46.2	40.9	47.3	32.5
10,000	55.9	52.0	50.5	40.9	48.4	40.0
30,000	50.7	52.0	61.3	43.0	52.7	48.8
MAGNESIUM						
0	0	0	0	0	0	0
10	23.8 ^{2/}	22.5	20.0	38.8	22.5	44.1
100	23.8 ^{2/}	23.8	20.0	48.8	30.0	51.6
1,000	30.0 ^{2/}	40.0	30.0	47.5	31.3	56.9
10,000	35.0 ^{2/}	50.0	35.0	51.1	31.3	58.1
30,000	50.0 ^{2/}	58.8	40.0	52.5	32.5	100
ALUMINUM						
0	0	0	0	0	0	0
10	33.3	29.2	25.0	28.1	34.8	25.8
100	35.9	31.4	25.0	29.2	39.3	31.4
1,000	43.8	34.0	25.0	38.2	40.4	34.8
10,000	56.2	40.0	32.0	38.2	42.7	40.4
30,000	100	40.4	32.0	39.3	44.9	47.2
AMMONIUM						
0	0	0	0	0	0	0
10	27.6	22.0	20.0	28.7	31.0	27.6
100	29.8	30.0	20.0	29.8	32.2	31.0
1,000	31.0	30.0	30.0	32.6	44.5	29.8
10,000	32.2	32.0	40.0	34.5	39.1	35.6
30,000	32.6	32.0	48.0	35.6	30.2	36.8

^{1/} Percent inhibition: Population of treated group calculated as percentage of control population.

^{2/} Percent increase.

increase of pH. This pointed to the fact that pH of these salts has a bearing on their toxicity to T. castaneum. Hence, further studies were carried out by enhancing toxicity of tricalcium phosphate by buffering action. In this series of experiments, standard buffer salts of pH 4, 6, 7, 8, and 9 were added to tricalcium phosphate. Table 2 shows that addition of buffer salts below pH 7 had a tendency to reduce the toxicity of tricalcium phosphate to T. castaneum, while incorporation of salts above pH 7 resulted in intensification of toxicity.

The enhancement of toxicity of monocalcium and dicalcium phosphate to T. castaneum by incorporation of buffer salts of pH between 8 and 9 also indicated that under alkaline conditions most of these salts were toxic to the insects. The gut pH of most of the stored grain insects as they are phytophagous ranges between 7 and 8 (Roeder 1953). Thus, it appears that not only are calcium and phosphorus effective in the toxic compounds but gut pH largely governs the toxicity potentials of the compounds.

Studies were also carried out to determine the enhancement of toxicity of tricalcium phosphate to insects by supplementation with salts, organic acids, amino acids, vitamins, and sugars. Increase or decrease in toxicity was based on insect populations in treated samples as compared with those in grain treated with tricalcium phosphate alone.

In general, mono-saccharides increased the toxicity of tricalcium phosphate to insects, while di-saccharides lowered its toxicity.

Enhancement of toxicity was exhibited by sodium chloride, sodium bicarbonate, magnesium sulfate, iron phosphate, and sodium bromide.

Effect of Calcium Phosphate on Major Stored Grain Pests

Laboratory cultures of adults of T. castaneum (red flour beetle), S. oryzae (rice weevil), C. chinensis (false beetle), T. granarium (khapra beetle), L. minutus (flat grain beetle), O. surinamensis (saw-toothed grain beetle), S. paniceum (drug store beetle) and larvae of E. cautella (almond moth), and C. cephalonica (rice moth) were selected for the studies. Calcium phosphate was incorporated with the respective media at 0.5-, 1.0-, 2.0- and 3.0-percent levels.

Table 2.--Effect of various buffer salts on toxicity of tricalcium phosphate to T. castaneum

Buffer	Concentration	Effect on toxicity	Statistical significance
pH 4	0.05	R	HS
	0.1		HS
	0.5		HS
	1.0		HS
	2.0		HS
pH 6	0.05	R	HS
	0.1		HS
	0.5		HS
	1.0		HS
	2.0		HS
pH 7	0.05	NP	HS
	0.1		HS
	0.5		HS
	1.0		HS
	2.0		NS
pH 8	0.05	P	HS
	0.1		HS
	0.5		S
	1.0		S
	2.0		HS
pH 9	0.05	P	S
	0.1		HS
	0.5		S
	1.0		HS
	2.0		HS

R = Reversion of toxicity of tricalcium phosphate. P = Enhancement of toxicity of tricalcium phosphate. NP = No potentiation. HS = Highly significant. S = Significant. NS = Not significant.

Table 3 shows that S. paniceum and T. granarium could tolerate a high concentration of tricalcium phosphate in their diets. E. cautella, C. cephalonica and L. minutus were highly susceptible to the toxic action of tricalcium phosphate at 1-percent concentration. Total mortality of S. oryzae and O. surinamensis was obtained even at the 2-percent level.

The histopathological changes in the larvae indicated the degeneration of midgut epithelium, blackening and necrosis of tissues, and depletion of fat. Weight reduction was more conspicuous in larvae than in other stages of insects.

The outstanding toxicity of tricalcium phosphate among all the other salts screened exhibits an involvement of both Ca and P in the salt. The mechanism of absorption of calcium phosphate from the diet of insects is not known. Urist (1964) speculated on "what animal life would be, if the two vital elements bound in the bone tissue--calcium and phosphorus--made a gel, instead of a hard substance." But, from the viewpoint of the body's chemistry, what matters is that this compound can be easily made and stored in the body and later broken down to assist in various metabolic processes. Calcium ions in the blood stream are essential to clotting mechanism and also to muscle contraction. Phosphorus metabolism is probably responsible for the superiority of the vertebrates over all other living things combined with fats, carbohydrates, and proteins. The breakdown and synthesis of glycogen would be impossible without the presence of phosphates.

Reviewing the findings reported herein, it becomes quite clear that substances which could inhibit the growth of insects need not have general toxicity to other forms of life. The growth inhibitory effect of tricalcium phosphate to insects belongs to this category. Although there are basic biochemical differences between insects and mammals, the comparative physiology of insects and mammals has not been exploited for the preferential control by retardation of insect growth in human foodstuffs. Evidence has been obtained that calcium phosphate is toxic to insects at low concentrations that are not likely to be harmful to man; rather, it is a desirable additive to human and animal foods.

Economical Application of Calcium Phosphate

To make economical application of tricalcium phosphate toxicity to stored foods for insect control, it was necessary to learn whether dibasic and monobasic calcium phosphate could serve as substitutes for tricalcium phosphate. Many industrial sources of calcium phosphate are available. These include superphosphate, basic slag, bonemeal, metaphosphate, bruschite, nonotite, hydroxylapatite, rock

Table 3.--Effect of calcium phosphate on the growth and breeding
of insect pests of stored foods

Insects and stages released	Growth medium	Concentration	Total population	Inhibition
		Percent	Number	Percent
<u>T. castaneum</u>				
6-day-old adults	Wheat flour	0	64	
		1	53	
		2	27	
		3	10	100
<u>S. oryzae</u>				
6-day-old adults	Sorghum (broken)	0	43	
		1	23	
		2	10	
		3	10	100
<u>E. cautella</u>				
1st instar larvae	Wheat (broken)	0	10	
		1	10	
		2	10	
		3	10	100
<u>C. cephalonica</u>				
1st instar larvae	Rice (broken)	0	10	
		1	10	
		2	10	
		3	10	100
<u>C. chinensis</u>				
2-day-old adults	Green gram	0	35	
		1	28	
		2	16	
		3	10	100
<u>L. minutus</u>				
5-day-old adults	Wheat semolina	0	41	
		1	10	
		2	10	
		3	10	100
<u>O. surinamensis</u>				
5-day-old adults	Copra meal + wheat flour (1:2)	0	36	
		1	13	
		2	10	
		3	10	100
<u>S. paniceum</u>				
1-to 2-day-old adults	Cumin	0	37	
		1	33	
		2	30	
		3	28	33.5
<u>T. granarium</u>				
1st instar larvae	Wheat (broken)	0	10 $\frac{1}{2}$	
		1	10 $\frac{1}{2}$	
		2	10 $\frac{1}{2}$	
		3	10 $\frac{1}{2}$	0

1/ Development to adults, no sign of inhibition.

phosphate, phosphatic nodules, silico phosphates, and gafsa rock phosphates. But unless these are beneficiated and purified so that pharmacological grades are produced, they cannot be used on foodstuffs.

To examine the relative effects of monocalcium, dicalcium and tricalcium phosphates, experiments were carried out using T. castaneum as test insects. Each salt was mixed with wheat flour at 1-, 2-, and 3.0-percent levels.

Dicalcium phosphate showed higher toxicity to T. castaneum than monocalcium phosphate, and the reduction of weight of adults was quite significant. Tricalcium phosphate showed maximum toxicity of the three. Examination of the pH of water extracts of monocalcium, dicalcium, and tricalcium phosphates, when incorporated in wheat flour at 1.0-percent level, showed the following pH values:

Monocalcium phosphate	-	pH 5
Dicalcium phosphate	-	pH 6
Tricalcium phosphate	-	pH 8.5

Industrial Application of Tricalcium Phosphate

Trials were made by mixing tricalcium phosphate in rice mills. Tricalcium phosphate was blown into the grain with a rotary duster at the discharge spout of the rice mill. The rate of flow of tricalcium phosphate was regulated in accordance with the discharge rate of milled rice. In these studies the enhancing effect of glucose was utilized. A premix of tricalcium phosphate (200 mesh) of commercial grade and glucose was prepared by mixing 95:5 by weight in a rotary mixer. The results obtained suggested the technological possibilities of introducing tricalcium phosphate as a formulation for protection of food grains from insect infestation even at concentrations below 1-percent.

High toxicity of the salt to pests of cereals and legumes (pulses) offers great possibilities for rendering grains and their products resistant to insect attack. Tricalcium phosphate exhibited a peculiar property of adhering to the grain surface without any difficulty, thus fairly uniformly coating the grain with the active ingredients. Visual and microscopic examination revealed that achieving a uniform coating on the grain surface was quite easy even with the equipment readily available.

Tumbling small amounts of grain in a container with a lid, a rotary mixer, a seed dressing drum, and feed mixing units could be carried out for different levels of application. The field trials carried out did not indicate any insect growth. This investigation has, therefore, opened up the possibility of rendering grain and grain products resistant to insect attack with a safe and specific protectant.

Cereal diets generally are deficient in calcium (Patwardhan 1956). A minimum need of 1,200 mg. of calcium per adult has been recommended by the nutritional advisory group (Whedon 1959, Boyce and King 1959). It is possible to enrich food grains and their products with calcium to meet nutritional needs and also to render them unsuitable for insect growth.

Conclusions

Complete inhibition of insect growth in food grains and milled products was obtained by incorporating tricalcium phosphate. Chlorides, carbonates, and bicarbonates, however, merely delayed the developmental period and, consequently, reduced the degree of population increase. The toxic action of all of these chemicals was exhibited by reduction in population, prolongation of life period, and attenuation of growth, time of emergence, and weights of insects.

Of the three calcium phosphates, tricalcium phosphate showed highest toxicity which was followed by dibasic and monobasic salts in decreasing order of toxicity to T. castaneum. Use of alkaline salts or buffers of alkaline pH significantly accentuated the toxic action of tricalcium phosphate.

Home-scale and mill-level trials on the incorporation of tricalcium phosphate premix with various commodities and subsequent storage of the treated materials showed consistently the inhibitory effect of the premix on stored-products insects. Thus, the possibility was demonstrated of utilizing the results of this investigation for protection of food grains from insect infestation with a specific grain protectant harmless to humans.

Acknowledgments

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Research Institute, Mysore, for his keen interest and constant encouragement in the study. Thanks is also given to the Council of Scientific and Industrial Research, India, for the financial grant of the research fellowship for the investigation at their laboratory.

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SAN FRANCISCO SOUR FRENCH BREAD
NOWHERE ELSE, WHY?

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SAN FRANCISCO SOUR DOUGH FRENCH BREAD, crisp-crust, chewy-textured, slightly sour French bread--made simply of flour, salt, water, and a glob of the mysterious "mother-sponge" or starter--has the gourmet world pounding at its "Golden Gate."

The widespread popularity of San Francisco sour dough French bread can best be observed at the San Francisco International Airport where hundreds of loaves are sold daily to people who carry them hundreds and thousands of miles as gifts for friends or family. This unique bread, as far as we know, is not made outside of a 50-mile radius of the San Francisco Bay area. To further verify this belief is the fact that thousands of loaves are commercially transported by air to distant cities such as Seattle, Los Angeles, Washington, D.C., New York, Chicago, and even Paris, France.

The obvious question arises: Why don't they make this bread elsewhere? Apparently, some have tried but they have not succeeded. According to one of the local bakers, they have given "starters" along with detailed instructions to many who have asked for help. Somehow "the starters" have managed to lose their "sour." The "mystery" of the San Francisco sour dough French bread was a unique challenge to us.

A literature search failed to bring out a single technical publication on sour dough French bread. This was the first of many roadblocks in our attempt to unravel the mystery of San Francisco sour dough French bread. The trade journals gave us a few popular articles describing the romantic history of this unique bread. The various authors seem to feel that the "starter" originated in southern Europe, more precisely the Basque country. In fact, one of the oldest bakeries here was founded over 100 years ago (during the Gold Rush days) by Basque immigrants.

It is interesting to note that local popularity of San Francisco sour dough French bread has increased over the years to approximately 20 percent of the bread consumed today.

To grasp the complexity of the problem, let us first examine the sour dough formulations (table 1). The starter-sponge is

Table 1.--Sour dough formulations

Starter sponge	Bread dough
100 parts previous sponge (40% of final mix)	20 parts starter sponge (11% of final mix)
100 parts flour (high-gluten flour)	100 parts flour (regular patent)
46 - 52 parts water	60 parts water
	2 parts salt
Starting pH 4.4 to 4.5	Starting pH 5.2 to 5.3
Final pH 3.8 to 3.9	Final pH 3.9 to 4.0

simply made up of 100 parts of the previous sponge, 100 parts of high-gluten flour, and 46 to 52 parts of water. Essentially it contains only flour and water with microorganisms transferred from the previous starter. Of great importance here is the "acidity" or pH range of the system. The starter begins with a pH of 4.4 and levels off at a pH of 3.9, an extremely acidic system. The final pH is comparable with that of mayonnaise. It is no small wonder that the starter has survived for so many years without being contaminated by other microorganisms. It takes about 8 hours for the starter to develop. It is then rebuilt in the same fashion about three times a day, 7 days a week. The bread dough is formulated with about 20 parts of starter sponge (11 percent of final mix), 100 parts of flour (regular patent), 60 parts of water, and two parts of salt. No sugars, shortening, NFMS, yeast foods, oxidizing agents, dough softeners and conditioners, etc., are used. After about 1 hour of floor time the bread dough is proofed for about 8 hours during which time its pH drops from about 5.3 to 3.9. The bread dough is baked for a relatively long time (45 to 50 minutes) at a relatively low temperature (375° to 390° F.) with low-pressure steam being introduced during approximately the first half of the baking cycle or until the crust begins to develop color. The live steam or wet oven is of critical importance to the eating quality of the crust as are the razorlike cuts made on the upper surface of the dough just before placing it in the oven. Baking is generally done directly on a carborundum hearth (fig. 1). There is little or no pH change during baking so that the bread has a pH of 3.9 to 4.0.



Figure 1.--Rotary hearth oven with steam fittings,

Sour dough French bread, superficially, seems so easy to make with so few ingredients but we must remember that the leavening as well as the souring must be accomplished by microorganisms. The "heart" of the process is a dynamic, living, biological system that requires definite environmental conditions. If the conditions are not right, the system may be invaded by other unfavorable microorganisms or it may just expire and fail to make a loaf of bread. But, with proper care, the mother-sponge or starter can be perpetuated indefinitely. We, at our laboratory, have carried a commercial starter for more than 2 years without any difficulty. Some of the local bakers have perpetuated their starters for over 100 years.

We examined mother-sponges from five different commercial sources for microbial flora. We isolated hundreds of pure cultures from the starters. All were found to contain the same rather unusual species of yeast (table 2), which was readily classified, in part by its inability to ferment or assimilate maltose and its ability to grow out well in the presence of Actidione (cycloheximide), an antibiotic inhibiting the growth of most yeasts.

Table 2.--Fermentation characteristics of sour dough yeasts

Yeast	Glucose	Sucrose	Raffinose	Galactose	Maltose	+ on Actidione
Baker's	+	+	+	+	+	-
Sour dough #1	+	+	+	+	-	+

Microscopically (fig. 2) the pure isolates were all typical yeast cells, globular to ovoid in shape, and showing "budding-fission" reproduction. Leavening action was found to correlate well with the presence and numbers of this strain of yeast, occurring at levels of 10 to 25 million cells per gram of mother sponge. Initial yeast levels in the bread doughs were about 2 to 4 million cells per gram of roughly 1/50th the level at which bakers yeast is used in conventional bread dough. The maltose-negative aspect of this yeast was very surprising since maltose is the principal fermentable sugar available in doughs prepared without addition of sugars.



Figure 2.--Sour dough yeast. X1000.

Our studies with pure cultures of the isolated sour dough yeast (fig. 3) confirmed its role as the leavening agent in sour dough and also demonstrated its unusual vigor and growth in a simulated sour dough environment (approximately 50 percent of the acidity

developed = acetic). Under the same conditions bakers yeast was found to die off. These pure culture studies also demonstrated, however, that the sour dough yeast was not involved in the souring mechanism.

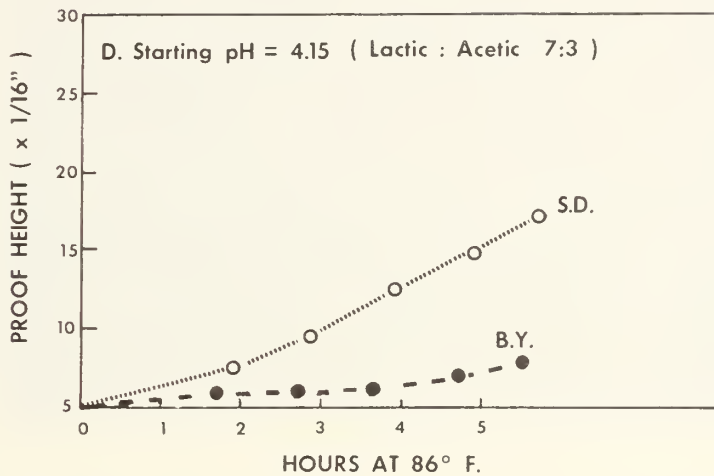


Figure 3.--Proofing ability of pure yeasts in simulated sour doughs.

A direct microscopic examination of the starter using staining techniques showed us beyond doubt that a bacteria was also involved in the process (fig. 4). Our initial attempts to isolate bacteria

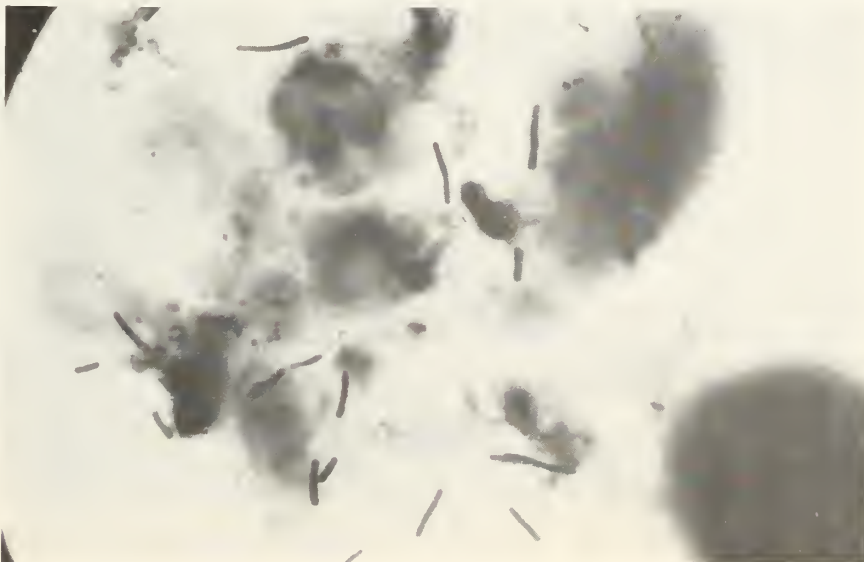


Figure 4.--Sour dough starter, showing yeast and bacteria. X1000.

of any type in appreciable numbers from sour dough French mother-sponges using several dozen plate count, lactic, acetic, anaerobic, coliform, etc. agar media alone or supplemented with flour and yeast extracts were unsuccessful. Eventually, it was found that an unusual combination of nutritional requirements, including an absolute requirement for maltose, was necessary to obtain growth on isolation media. This requirement for maltose dovetails, fortunately, with the finding that the sour dough yeast doesn't utilize maltose. Heavy growth of these bacteria in 1 to 2 days was then achievable and permitted their enumeration. Bacterial counts in the various mother-sponges ranged from $1/2$ to $1\ 1/2$ billion cells per gram or roughly 50 to 100 times as numerous as the sour dough yeast cells. The bacteria were similar or identical from the various sources and morphologically varied in appearance from short rods to involuted, swollen, and filamentous forms all derivable from a pure culture (figs. 5, 6 and 7). These bacteria do not appear to fit any known taxonomic position, and considerable work remains on their nutritional, morphological, taxonomic, and biochemical aspects.



Figure 5.--Sour dough bacteria. X1000.



Figure 6.--Sour dough bacteria, involuted and swollen forms. X1000.



Figure 7.--Sour dough bacteria, filamentous form. X2000.

At present, we are striving to grow out the sour dough bacteria in quantities suitable for use in actual breadmaking tests--this will be the "acid" test. If our pure culture isolates of sour dough bacteria produce the acids in comparable quantities to give the bread its characteristic aroma and tartness, we will have solved the mystery of the "sour."

In summary, we are systematically unraveling the mystery of the San Francisco sour dough French bread. The major clues uncovered so far are: (1) The yeast responsible for the leavening power has been isolated and identified; (2) the sour producing bacteria has been isolated; (3) why the process is self-sustaining has been established; (4) proofing can be accelerated and volume improved by the judicious use of bakers yeast; and (5) it is not necessary to rebuild or transfer the mother-sponge three times a day, 7 days a week. Under proper conditions, three times a week is all that is necessary.

We hope that the practical applications of our findings may possibly include some of the following: (1) placing our local sour dough French bread production on a sound scientific basis, uniformly active starters and predictable schedules; (2) helping others, wherever they may be, to produce a similar product; and (3) the possibility of enhancing the flavor of our "continuous-mix bread by spiking with a liquid sour dough mother-sponge.

This project was headed by Leo Kline, biochemist, and assisted by Mrs. Linda B. McCready, food technologist.

DRY AIR EXPANSION TO IMPROVE GRAINS FOR FEED

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In view of the prevailing wheat prices in some areas, the subject of improving the feed value of wheat by dry air expansion has been expanded to include a brief look at the utilization of whole wheat in animal feeds. This subject was reviewed at the 3rd National Conference on Wheat Utilization Research by Dr. McGinnis of Washington State University in a discussion of poultry feeds (1) and at the 4th National Conference on Wheat Utilization by Dr. Dahmen in a discussion of cattle feeds (2). Researches reported by these men and most work carried out subsequently by various groups have shown that wheat is an effective nutritional substitute for other local grains when economic factors are favorable. This applies equally to poultry, swine, and ruminant rations (see, for example, 3,4,5). As previous speakers have pointed out, much of the time the price of wheat is so high that only food outlets are economically feasible. However, occasionally, as in the past year, price levels have been such that feed use is practical. The present dry-mixed feed industry, with modern concepts of balanced rations, is willing to consider any material as a feedstuff if the price is right. For example, data compiled by the U.S. Department of Agriculture show that feed use of wheat increased from 57 million bushels in 1967 to 175 million bushels in 1968, and may rise to 225 million bushels this year (6). This latter figure represents almost 15 percent of our total wheat production for a year. Last year only 33 percent of this wheat was consumed on farms where it was grown, with the remainder going to feedlots and commercial feed manufacturers.

Table 1 shows that compositionwise the major feed grains

Table 1.--Comparative feed analysis (1968
feedstuffs analysis table)

Ingredient	Corn			
	(yellow)	Wheat	Barley	Milo
Protein, percent	8.9	11.25	10	9
Fat, percent	3.8	1.5	1.8	2.5
Fiber, percent	2.9	2.3	7.0	2.7
Ash, percent	1.5	1.5	2.5	1.5
M.E., poultry,Kcal./lb.	1,530	1,360	1,060	1,480
TDN, ruminant, percent	80	76	78	79

are very similar (7). Generally, wheat has somewhat more protein than corn, so theoretically less protein supplement is needed. Both, however, require supplementation because they are deficient in lysine, and corn is uniquely low in tryptophan. Corn seems to offer slightly more energy than wheat, part of this being due to higher fat content of the corn. The low fat content of wheat makes some nutritionists wonder whether there may be a lack of essential fatty acids when wheat is substituted for corn in poultry rations (8). Wheat also lacks the xanthophyll that corn can supply to poultry diets. This ingredient imparts desirable coloring characteristics to egg yolks and broiler skin, so that in the case of wheat rations, it must be completely supplied by other sources. Neither milo nor barley are xanthophyll sources either, so wheat can compete well with these grains in poultry diets in areas where corn is not the important local grain.

Wheat competes with corn primarily as an energy source in feeds in the Midwest. We have calculated least-cost milking and beef finishing rations for a Midwestern location in the fall of 1968 using our own program and find that substantial amounts of wheat are included when the prices of wheat and corn are equal. In the Northwest, wheat competes most strongly with barley; in California and the Southwest, with both barley and milo. Our calculations of least cost poultry rations for a California Central Valley location in the fall of 1968, when feed wheat and milo were priced equally, show wheat displacing milo completely in a layer ration formulated at 1,350 Kcal./lb. and providing over half the grain in a broiler finisher ration formulated at 1,450 Kcal./lb. A cattle feeding test of Sonora 64 wheat and barley, reported at the 9th California Feeders Day, October 31, 1969, showed that both grains were comparable in feeding value, and that a combination of the two grains may stimulate slightly better gains but will give no better feed efficiencies (9).

The result of this test is similar to many others reported for cattle feeding studies. The tendency in the past has been to steer clear of all-wheat rations, using wheat for not more than about one-half to two-thirds the total grain in the diet. For cattle some believe there is a palatability problem with wheat and that animals tire of it after prolonged feeding (10). Modern pelleting procedures that could be used to overcome this difficulty are not generally applicable at most cattle fattening yards.

To improve the feed value of wheat and other grains in today's high-concentrate cattle fattening rations, most feedlot operators routinely process their grains. Most often they use an atmospheric steaming and flaking procedure. We, along with other groups, have investigated the dry heat expansion of grains, or popping, as an alternative process (11,12,13,14). This process uses dry heat to vaporize the natural moisture in the grain, creating steam inside the individual cells. The hot steam disrupts

the organized structure of the starch granules, gelatinizing them and making them more digestible. Figure 1 shows microscopic views

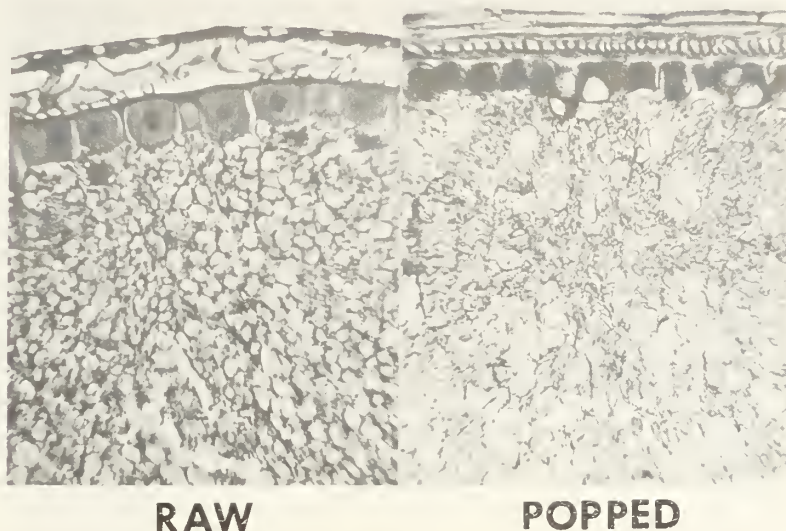


Figure 1.--Cell structures in raw and popped wheat observed microscopically.

of popped and raw wheat. The clearly visible starch granules of the raw wheat are no longer distinguishable in popped material. Instead, they have been blown up during the popping process, in many cases without even breaking the cell walls (15). Note that the thick-walled cells of the aleurone layer are not disrupted by this treatment.

On Wednesday most of you saw the grain popper designed by the Engineering group at WRRL and saw some typical product. Milo actually pops like popcorn with some grains increasing 9 to 13 times in size, but wheat and barley merely expand to about 1-1/2 times their original size. Figure 2 shows popped milo, figure 3 some expanded WURLD wheat (a peeled wheat product), and figure 4 shows puffed rolled wheat ready for feeding. Table 2 shows that starch digestibility in cereal grains (judged by in vitro tests with α -amylase) is increased by the dry air expansion technique. Also, the increase in digestibility can be controlled by regulating the moisture level in the grain prior to processing as shown in table 3.

In 1968, we cooperated with Agway, Inc. and the University of California at Davis in a cattle finishing trial comparing the performance of processed wheats and milos. Process treatments included popping, atmospheric-steaming and rolling, and pressure-steaming and rolling (two different pressures). Figures 5 and 6 show some of the test animals and part of the test facility at Davis. Acceptability of the popped grain rations was high. Table 4 shows the result of the wheat feeding portion of the experiment



Figure 2.--Sample of popped milo separated to show the proportions of grains highly expanded, moderately expanded, and very slightly expanded



Figure 3.--WURLD wheat (bran removed with alkali) after puffing



Figure 4.--Wheat after puffing and then rolling.

Table 2.--In vitro digestibility of popped grains

Grain	Moisture percent	Treatment	Digestion period		
			1 hr.	4 hr.	24 hr.
			Mg. glucose/g. dry weight		
Barley	10.5	raw	14	38	95
		popped	168	247	381
Red wheat	14	raw	11	33	72
		popped	154	241	376
White wheat	11	raw	11	29	80
		popped	54	100	168
Yellow corn	14	raw	44	87	175
		popped	89	163	252

(16). All the process treatments (popping; 1.5 minutes steaming at 50 p.s.i., or 80 p.s.i.; or 8 minutes steaming at atmospheric pressure) gave excellent results in regard to gains and carcass characteristics with popped wheat about in the middle. The feed efficiencies in all cases were above average feedlot performance

Table 3.--In vitro digestibility of grains popped at elevated moisture levels

Grain	Treatment	Moisture	Digestion period		
		level	1 hr.	4 hr.	24 hr.
		Percent	Mg.	glucose/g. dry weight	
Red wheat	Control	14	13	33	72
	Popped	14	154	241	376
	Popped	17.5	137	231	368
	Popped	20	190	306	465
	Popped	25	222	350	504
White wheat	Raw	11	11	29	80
	Popped	11	54	100	168
	Popped	15	90	152	259
	Popped	17.5	155	249	360
	Popped	20	174	272	389
	Popped	25	201	313	437



Figure 5.--Test animals and feedlot facilities in feeding trials carried out at Davis, Calif.



Figure 6.--Test animals and feedlot facilities in feeding trials carried out at Davis, Calif.

Table 4.--Effect of processing wheat on fattening of steers

Treatment	Popped	Processing method		
		1.5 min. at 50 p.s.i.	1.5 min. at 80 p.s.i.	8 min. at atmospheric pressure
Number of animals	12	12	12	12
Average days fed, number	163	163	163	163
Initial shrunk wt., lb.	481	488	479	489
Final shrunk wt., lb.	921	901	894	937
Daily wt. gain, lb.	2.70	2.54	2.55	2.75
Feed/wt. gain, lb.	5.54	5.68	5.63	5.76

with popped wheat superior but not significantly so. The results might have been different if the experiment had been run at a commercial feedlot where the workers were less skillful in the grain flaking operation. Careful flaking is essential to give highly digestible steamed or pressure-cooked products but it is unimportant with a popped product.

As an outgrowth of our work on grain popping, one large company in Texas is now manufacturing a grain popper capable of handling 4 tons per hour for feedlot use. Processing costs are claimed to be \$1 per ton less than for an atmospheric steaming and flaking operation. The economies stem largely from lower power, labor, and materials-handling costs. An additional benefit seems to be that the palatability of popped material is so good that animals take less time to get on feed and generate higher-than-ordinary initial gains. Most of the machines are now being bought to process milo in Texas, but at least one feedlot operator in Kansas has purchased a commercial machine and is processing wheat with considerable success. Interest is also developing in the corn and barley producing areas. If present trends are maintained, grain popping to produce high efficiency cattle feed promises to become a widespread practice.

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BIOLOGICAL AVAILABILITY OF NUTRIENTS AND COMPUTER
EVALUATION OF MILLFEEDS

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Wheat bran and shorts give relatively low metabolizable energy (M.E.) values and poor protein utilization when fed in poultry diets. Steam pelleting these wheat mill feeds has been shown by Cave, Summers, and Slinger to increase the M.E. in bran and shorts by as much as 30 and 17 percent, respectively. For several years workers have been searching for an explanation of the causes behind this M.E. increase. We have shown that this increase is, in part at least, due to better utilization of the nutritionally rich aleurone layer.

The aleurone cells of wheat comprise a single layer of cells on the outside of the endosperm. Morphologically they are a part of the endosperm, but they become a part of the shorts and bran fractions upon commercial milling. The aleurone cells comprise about 7 percent of the wheat kernel and about 40 percent of wheat bran. Furthermore, about 75 percent of the protein, 90 percent of the fat, and almost all of the B vitamins of bran are in the aleurone component.

Today I shall present the evidence which proves that the nutritional upgrading of bran and shorts is due to rupturing of the aleurone cells. I will also present some results that show how the computer can be used to evaluate millfeeds and upgrading processes.

We fed bran, pelleted crumbled bran, shorts, and reground shorts to chicks. The wheat mill fraction comprised 100 percent of the diet. From samples of intestinal contents and pooled fecal samples, the fate of the aleurone cells was followed by microscopy, protein, and amino acid analysis.

Figure 1 shows a section of the aleurone layer isolated from chick feces after feeding bran. Figure 2 shows another section of the aleurone layer after feeding pelleted bran, again isolated from the feces. Note the empty cells; the dark cells contain fat and protein, whereas the light cells are completely empty. Note that all empty cells have one outstanding feature in common, a ruptured cell wall.

^{1/} Economic Research Service, ARS, USDA

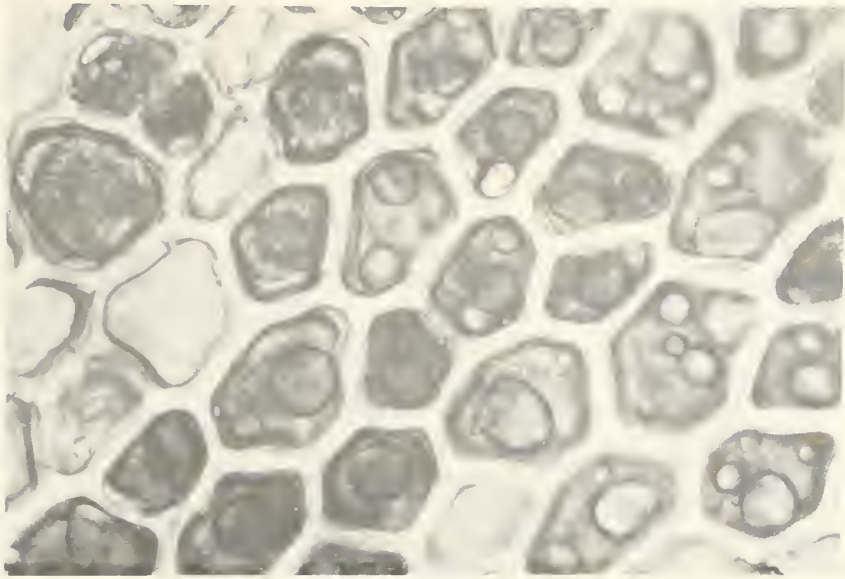


Figure 1.--Aleurone cells present in feces after feeding wheat bran to chicks. X 105.

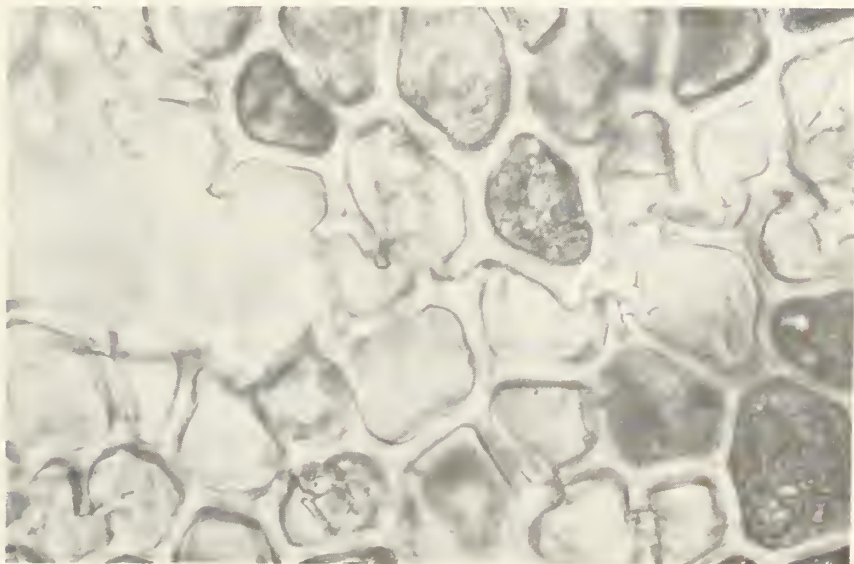


Figure 2.--Cell-wall breakage in aleurone cells present in feces after feeding steam-pelleted wheat bran to chicks. X 105

Table 1 shows the results of a typical experiment in which

Table 1.--Number of intact aleurone cells and residual protein in wheat bran and shorts feeds after digestion by chicks

Item	Intact	Protein in
	aleurone cells	feces
	<u>Percent</u>	<u>Percent</u>
American bran	78.6	8.38
American pelleted and crumbled bran ¹	60.0	6.38
Canadian bran ²	67.2	7.12
Canadian pelleted and crumbled bran ²	49.8	6.27
Shorts ³	51.0	6.44
Reground shorts ⁴	29.6	5.14

¹ HRS Midwest wheat pelleted with a California Pellet Mill, 16-percent moisture, 1/4 inch die.

² Generously supplied by J. D. Summers, Canadian hard red spring wheat.

³ Generously supplied by International Milling, HRS North Dakota wheat.

⁴ Same shorts as footnote 3 but reground three times through a Brabender quadrumat senior roll mill.

the actual number of empty aleurone cells was counted, and protein determined in the particulate fraction of the feces which was isolated by severely agitating the feces in water and filtering through a fine nylon mesh (0.007 inch diameter openings) and thoroughly washing with running water. Feathers were removed manually. The difference in aleurone cell count and the particulate protein between the pelleted and unpelleted samples was statistically significant at 95-percent confidence level. With the pelleted ration the number of empty aleurone cells was substantially higher than in the unpelleted ration. Moreover, the particulate protein content was proportional to the number of intact aleurone cells.

Table 1 also shows the results observed when feeding a shorts and reground shorts ration to chicks. A similar result was obtained; increased aleurone cell wall breakage resulted in a decrease in fecal particulate protein, or an increase in protein utilization. These experiments and similar ones not reported at this time demonstrate that increased aleurone cell wall breakage results in better protein availability.

In an effort to follow protein digestibility more conveniently, an in vitro system was devised whereby the feed sample is digested first by "Pronase," a proteolytic enzyme, and then by a chick pancreas amylase prepared in our laboratory. Reproducibility of the in vitro method is within 1 percent and it has been successfully used to determine protein availability on several foods and feeds. Microscopy showed that intact aleurone cells of bran were not digested at all by this dual enzyme digestion method, whereas the contents of ruptured cells were completely digested. The amino acid distribution pattern for the residue after digestion of unpelleted bran by in vitro and in vivo methods (that is to say, the in vivo residue in the washed particulate fraction of the feces) were almost identical. Figure 3 compares the percent distribution of recovered amino acids from bran digested by the two methods. Figure 4 shows the amino acid pattern of bran and shorts digested by the in vitro procedure. That they are virtually identical shows that the indigestible residue from bran and shorts has come from the same source,

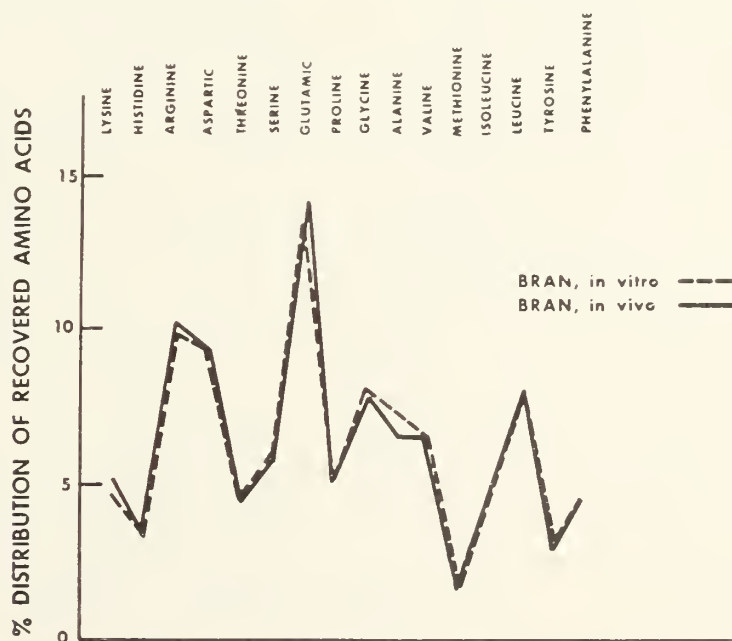


Figure 3.--Percent distribution of amino acids in nondigestible protein of wheat bran after in vivo or in vitro digestion.

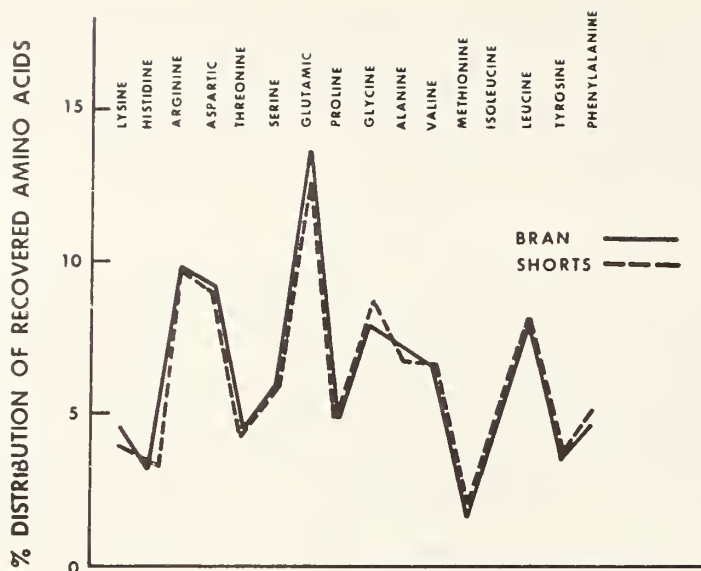


Figure 4.--Percent distribution of amino acids in nondigestible protein of wheat bran and wheat shorts after in vitro digestion.

for example, intact aleurone cells.

Thus, we had developed a rapid simple procedure for measurement of protein digestibility. We then undertook to apply this method to the practical problems at hand. Wheat bran was processed by a number of different milling techniques. The percent digestible or "available" protein was measured by the in vitro technique. We found that protein availability after grinding tended to be proportional to bran particle size. Protein availability in wheat bran, normally about 70 percent, could be increased to well over 90 percent by different milling procedures. Steam pelleting was more beneficial than certain millings. Autoclaving actually caused a slight decrease in protein digestibility. Turning back to figure 1, I should like to point out the globular bodies which are clearly visible. These globules can be stained with a fat stain. We have never seen these globules in ruptured aleurone cells nor in cells before digestion. The appearance of these globules suggests a physical change in the nature of the fat within the cell during the course of digestion--both in vivo and in vitro. The exact reason is not known at this time. In an experiment with some of the same milled brans mentioned above, ether extractable fats were measured. Extractable fat, which we can only assume at this time is utilizable in vivo, did indeed increase as aleurone cell wall rupture increased, and in a manner similar to the increases in protein availability. This would account in part for the M.E. increase found for pelleted bran compared with unpelleted bran.

Experiments with different breads containing mill fractions have shown that the baking process does not rupture the aleurone cells.

In summary, the work we have described shows that pelleting wheat bran causes breakage of aleurone cell walls whereby the nutritionally rich contents are made available to digestive enzymes. Actual increase of digestible protein has been measured by a chick feeding assay and by a pronase-chick pancreas amylase in vitro procedure. Further changes in digestible protein as measured by the in vitro system can be brought about by milling of wheat bran and wheat shorts. The phenomenon of aleurone cell wall rupture during pelleting would explain at least in part the increase in M.E. in pelleted wheat bran and shorts compared with the unpelleted material.

About 68 percent of the mixed feed produced in the United States today is computer formulated. The method is called linear programming (L.P.) for least cost formulation. This method enters all of the nutrient values of all feedstuffs available and the prices of these feedstuffs into the computer's memory bank. This includes such items as amino acid composition, vitamins, metabolizable energy, Ca, and P. The nutritional requirements of all classes of livestock are stored in another section of the computer. You then tell the computer which animal you are interested in, what age, etc., and tell it to go. In a few minutes you have an answer that tells you the lowest cost combination of feed ingredients which will supply the needed requirements.

Several years ago I had the idea that we needed a tool to decide whether a potential new feed product was worth working on and how big the potential market would be at different prices. We were able to set up a cooperative project--Agricultural Research Service, USDA, Economic Research Service, USDA, and Monsanto Chemical Company--which led to the first application of a modified L.P. system to an economic study of a feed ingredient, alfalfa meal. The new procedure is called Parametric Linear Programming (P.L.P.). We are presently using the Monsanto Computerized Technology like L.P. with one big difference. The ingredient to be studied, for example, wheat middlings (table 2) is initially offered at a ridiculously high price, say \$200 per ton. The computer calculates the least cost ration, in this case for pullet developer ration for heavy type birds. At the \$200 per ton price, mids are, of course, rejected. In P.L.P., however, the computer is programmed to recycle each time reducing the price of mids a small increment, say of 1¢ per ton. Eventually, the mids get cheap enough to be accepted in the least cost ration at a specific level. In this case (table 2) at a price of \$3.23 per hundredweight (\$64.63 per ton), about 5 percent is included in the least cost ration.

Continuing to reduce the price of mids brings in greater and greater amounts in the least cost ration--until finally if you give away the mids about 62 percent would be used. This array of data yields a "price-demand" curve. Here I must emphasize that the "price" the computer comes up with in P.L.P. is really the true worth of the product based on the prices of all other ingredients available. If the actual market price of the mids is over the P.L.P. worth, the seller is getting more for his product than it is worth from a nutritional standpoint. The next several tables are included to show that the computer tells us a lot more about feeds. Table 3 shows the least cost ration before the first acceptance of mids. The printout tells us the composition, blending instructions for a ton of feed, and how much each ingredient costs and contributes to diet cost.

Table 2.--Computer printout, wheat middlings in pullet developer ration

START PCR WITH KEY INGREDIENT WHEAT MIDLINGS

PARAMETRIC MULTIPLIER	DIET COST	PRICE OF KEY INGREDIENT	AMOUNT IN DIET	SAVE DATA
6.76824	2.65985	3.23176	5.08379	
6.80108	2.65818	3.19892	10.60241	1
6.95530	2.64183	3.04470	18.31040	1
7.48464	2.54490	2.51536	19.65871	1
7.58841	2.52450	2.41159	23.87931	
7.87074	2.45708	2.12926	26.90857	1
8.08359	2.39981	1.91641	27.41088	1
8.09120	2.39772	1.90880	28.68775	1
8.24565	2.35341	1.75435	29.83402	1
8.61272	2.24390	1.38728	30.13931	1
9.09014	2.10001	.90986	50.91071	1
9.26960	2.00865	.73040	58.37704	1
9.30094	1.99035	.69906	61.47098	1
10.00000	1.56350	.00000	62.19284	

END PCR CALC. MAX. MULT. = 10.00000

The next printout (table 4) shows how much of each nutrient is supplied by the least cost ration in relation to requirement and also

Table 3.--Computer printout, least cost ingredients for pullet developer ration

U.S.D.A. W.U.R.D.D. Poultry AND SWINE MATRIX
 REPLACEMENT PULLET DEV
 DIET 3 FIXED WT.
 OCT 31
 #1 COMPOSITION AND COST

SCALE READING	AMOUNT IN MIX	INGREDIENT NAME	PERCENT	INGREDIENT COST	DIET COST
934.72	934.72	CORN, YELLOW	46.7359	2.08	.97
1371.10	436.38	BARLEY	21.8192	2.57	.56
1691.87	320.77	SOYBEAN MEAL-44%	16.0385	3.86	.62
1697.36	5.48	MEAT&BONE M. 50	.2741	4.24	.01
1847.36	150.00	DEHY ALF 20	7.5000	3.24	.24
1947.36	100.00	RICE BRAN	5.0000	2.67	.13
1958.82	11.47	CALCIUM CARBONATE	.5733	.60	.00
1986.36	27.54	DICAL PHOSPH-18.5%	1.3768	4.03	.06
1986.61	.25	FIXED ING. WEIGHT	.0125	111.82	.01
2000.00	13.39	FIXED ING. ENERGY	.6696	7.00	.05
	2000.00		100.0000		2.66
COST PER 100 LBS.		2.66			
COST PER TON		53.20			

Table 4.--Computer printout showing nutrients supplied in least cost ration

U.S.D.A. W.U.R.D.D. Poultry AND SWINE MATRIX
 REPLACEMENT PULLET DEV
 DIET 3 FIXED WT.
 OCT 31
 #2 RESTRICTION ANALYSIS

RESTRICTION NAME	AMOUNT SPECIFIED	AMOUNT IN RATION	MARGINAL VALUE/UNIT
WEIGHT REQUIREMENT	100.0000	100.0000	-3.9132
MET. E. CAL/LB MIN	1250.0000	1250.0000	.1245
PROTEIN MIN %	.0000	15.5235	.0000
ARGININE MIN %	.7500	.9025	.0000
GLYCINE MIN %	.6250	.6250	-12.4020
ISOLEUCINE MIN %	.4688	.6945	.0000
LYSINE MIN %	.6875	.6875	-38.4634
METHIONINE MIN %	.2500	.2547	.0000
METH+CYSTINE MIN %	.4688	.4991	.0000
THREONINE MIN %	.4375	.5988	.0000
TRYPTOPHAN MIN %	.1250	.2095	.0000
AVAIL PHOS. MIN. %	.4018	.4018	-11.2355
CALCIUM MIN %	.5357	.7357	.0000
ADDED FAT MAX %	10.0000	.0000	.0000
FIBER MAX %	100.0000	5.9874	.0000
XANTH MIN MG/LB	2.6786	14.7062	.0000
CHOLINE MIN MG/LB	.0000	471.1798	.0000
VIT. K MG/LB MIN	.0000	.4995	.0000
A TOCOPH MG/LB MIN	.0000	7.0614	.0000
T VIT A MIU/LB MIN	.0000	12.9260	.0000
RIBOFLV. MG/LB MIN	.0000	1.2527	.0000
FOLIC A. MG/LB MIN	.0000	.3384	.0000
NIACIN MG/LB MIN	.0000	22.3734	.0000
PANTO. A MG/LB MIN	.0000	4.6971	.0000
FISHMEAL MAX %	10.0000	-.0000	.0000
FIXED ING. WT. %	.0125	.0125	-107.9068
FIXED ING. ENRG. %	.6696	.6696	-3.0868
TOTAL FAT MAX %	100.0000	2.5834	.0000

tells us which nutrients are costing money (that is, "pressure points"). We see that phosphorus and the amino acids, lysine and glycine, are critical in this formulation. Table 5 shows a sample of printout which illustrates what would happen if prices of the accepted ingredients were changed. For example, if the price of corn went from \$2.08 to \$2.12, the corn would be replaced by milo. If the price of barley dropped from \$2.57 to \$2.08, more would come into the least cost ration and the glycine pressure point would be eliminated. Table 6 illustrates another block of information we get from the computer on ingredients initially rejected for the least cost ration. For example, we see that if the price of milo dropped just 3¢ per hundredweight (from \$2.20 to \$2.17 per cwt.), it would have gone in in place of corn. If the price of wheat dropped from \$2.43 to \$2.36, 7.56 percent would have entered the least cost ration. As noted here, the mids were priced in at \$200 per ton or \$10 per hundredweight since this was to be a P.L.P. study of mids. The \$3.23 per hundredweight entry price here is the first P.L.P. point we have already seen in table 2.

I would next like to show you how we can use P.L.P. to evaluate research potentials. Table 7 shows the results of a study of wheat mids as they are today and a theoretical wheat mids improved by increasing the biological availability of nutrients. The availability of the energy and amino acids as we have shown can be improved by disruption of the aleurone cells. The phosphorus would have to be liberated from the cells and also chemically released from phytin, its bound form. From the table we see that in a 1,300-calorie layer ration, mids have a P.L.P. value of \$43.30 at the first entry point above 5 percent. If the amino acids were made completely available, the mids value jumps to \$47.82, a gain of \$4.52. Increasing the M.E. by 25 percent would up the value by \$1.29 per ton. Increasing phosphorus availability to 100 percent would increase the value of the mids by \$2.66. Increasing all of these at once brings about an increase of \$9.15 to \$52.45. We have dubbed this theoretical product "Super Mids."

Let us next take a look at a higher energy layer ration formulated for cold weather use. Here we see that mids is apparently not in the picture. Even Super Mids with a \$15.67 value margin over regular mids is worth only about \$35.00 per ton.

Table 8 shows how mids and Super Mids work out in a few selected swine, dairy, and poultry rations. In the swine-grower ration the increase is \$7.64 per ton. The value of mids in a broiler finisher ration was so low we didn't bother to run Super Mids. In a broiler replacement pullet developer ration, the mids show up very well at \$64.63 per ton at the 5-percent level and \$50.31 at a 19-percent use level. Super Mids are worth about \$12 per ton more than regular mids.

Table 5.--Computer printout showing changes in formulation with
changes in prices of ingredients

U.S.D.A. W.U.R.D.D. Poultry and Swine Matrix
Replacement Pullet Dev
Diet 3 Fixed WT.
Oct 31
#3 Price Sensitivity of Accepted Ingredients

Ingredient in Blend	Activity Changing	Lower Limit	Unit Cost	Upper Limit	Activity Changing
CORN, YELLOW	COTTONSEED SOLV-	1.59	2.08	2.12	MIL0
BARLEY	GLYCINE OVER MIN	2.08	2.57	2.72	MIL0
SOYBEAN MEAL-44%	LYSINE OVER MIN	3.19	3.86	4.02	SOYBEAN MEAL-49
MEAT&BONE M. 50	GLYCINE OVER MIN	3.63	4.24	6.07	FEATHER M. 85
DEHY ALF 20	* * NO LOWER LIM	.00	3.24	3.44	LEAVES UPPER BN
RICE BRAN	* * NO LOWER LIM	.00	2.67	3.46	LEAVES UPPER BN
CALCIUM CARBONATE	FEATHER M. 85	-14.59	.60	2.92	DEFL. PHOSPHATE
DICAL PHOSPH-18.5%AVAIL.	PHOS.OVER	1.97	4.03	4.84	DEFL. PHOSPHATE
FIXED ING. WEIGHT	* * NO LOWER LIM	.00	111.82	99.99	* * NO UPPER LI
FIXED ING. ENERGY	* * NO LOWER LIM	.00	7.00	99.99	* * NO UPPER LI

Table 6.--Computer printout showing prices at which rejected in-
gredient would be included in formulation

U.S.D.A. W.U.R.D.D. Poultry and Swine Matrix
Replacement Pullet Dev
Diet 3 Fixed WT.
Oct 31
#4 Acceptance Prices for Rejected Ingredients

Ingredient Name	Ingredient Cost	Acceptance Price	Acceptance Level	Reduced Activity
MIL0	2.20	2.17	59.35	CORN, YELLOW
WHEAT, HRW	2.43	2.36	7.56	MEAT&BONE M. 50
COTTONSEED SOLV-41	4.14	3.71	1.40	MEAT&BONE M. 50
SOYBEAN MEAL-49%	4.15	3.97	14.11	SOYBEAN MEAL-44%
CORN GLUTEN M. 60	5.50	2.52	1.55	MEAT&BONE M. 50
FISH M. 70 HER.	8.50	4.98	1.85	MEAT&BONE M. 50
FISH M. 62 MEN.	7.13	4.41	1.48	MEAT&BONE M. 50
FISH M. 65 PER.	6.59	4.51	.89	MEAT&BONE M. 50
MEAT MEAL 55 %	1000.00	4.47	.25	MEAT&BONE M. 50
FEATHER M. 85	5.11	3.63	.34	MEAT&BONE M. 50
POULTRY BYPR0D-55%	6.46	3.57	1.20	MEAT&BONE M. 50
SAFFLOWER M. 42	1000.00	3.80	.95	MEAT&BONE M. 50
WHEAT MIDDINGS	10.00	3.23	5.08	MEAT&BONE M. 50
FAT, ANIMAL	5.59	-.54	1.54	METH OVER MIN
FAT, HYD VEG+ANIMAL	1000.00	-.69	1.49	METH OVER MIN
DEFL. PHOSPHATE	3.70	2.98	1.54	DICAL PHOSPH-18.5%
LYSINE 50	62.50	23.14	.04	METH OVER MIN
MHA	82.00	3.91	4.69	BARLEY
VIT A 1.475 MMU/L	5.48	2.17	59.35	CORN, YELLOW
VIT K (1.28 G/LB)	4.56	2.17	59.35	CORN, YELLOW
VIT E(1250 IU/LB)	5.95	2.17	59.35	CORN, YELLOW
CHOLINE CL-.50%	2.34	2.17	59.35	CORN, YELLOW
RIBOFLAVIN .20 G/L	2.70	2.17	59.35	CORN, YELLOW
FOLIC ACID .01%	2.87	2.17	59.35	CORN, YELLOW
D-CA PANT. .2 G/LB	2.30	2.17	59.35	CORN, YELLOW
NIACIN 1. G/LB	2.55	2.17	59.35	CORN, YELLOW

Table 7.--Preliminary parametric L.P. study of wheat middlings

Ration	M.E. requirement <u>Kcal/lb.</u>	Modifi- cations	Amount in ration <u>percent</u>	Entry price <u>Dollar per ton</u>	Increased value <u>Dollar per ton</u>
Layer light breeds summer	1,300	--	5.1	43.30	--
DO	1,300	A.A. in mids at 100% available	5.2	47.82	4.52
DO	1,300	M.E. in mids incr. by 25%	5.3	44.59	1.29
DO	1,300	Phosphorus in mids to 100% available	5.3	45.96	2.66
DO	1,300	A.A., M.E. and P in- creased in mids (Super Mids)	5.4	52.45	9.15
Layer light breeds winter	1,350	--	16.2	18.83	--
DO	1,350	M.E. in mids increased by 25%	14.2	27.03	8.20
DO	1,350	A.A., M.E. and P in- creased in mids (Super Mids)	8.0 17.5	34.81 34.50	-- 15.67

Included in this table is a P.L.P. value for mids in a 42-percent dairy supplement. The value is high as expected since the major uses of mids are in ruminant rations and the feed manufacturers also have computers. At present there is no indication that mids can be upgraded for ruminants so the term Super Mids refers only to nonruminant uses.

Table 8.--Preliminary parametric L.P. study of wheat middlings

Ration	M.E. requirement Kcal./lb.	Modifi- cations	Amount in ration percent	Entry price Dollar per ton	Increased value Dollar per ton
Swine grower (60-100 lb.)	1,420	--	5.9	38.33	--
DO	1,420	A.A., M.E. and P in- creased in mids (Super Mids)	7.8 (3.8)	45.97 (49.09)	7.64 --
Broiler finisher	1,450	--	21.4	14.21	--
Replacement pullet developer heavy breeds	1,250	--	5.1 19.7	64.63 50.31	--
DO	1,250	A.A., M.E. and P in- creased in mids (Super Mids)	16.8 37.3	62.29 51.39	11.98 --
42% Dairy supp. 50% (T.D.N.) ^{1/}		--	17.0	53.75	--

^{1/} Total dry nutrients.

These computer studies thus tell us that the potential gain in dollar value of mids from increasing nutrient availability ranges from about \$8 to \$15 per ton. Our present work is directed toward practical minimum cost procedures to make such a product.

In summary, it has been demonstrated that wheat millfeeds can be upgraded in value by increasing biological availability of nutrients. Computer techniques for evaluating feed products indicate that the increases in value are great enough to justify a very considerable research and development effort along these lines.

POLLUTION-FREE SEPARATION OF STARCH AND FLOUR PROTEINS

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When a process exists where 10 to 15 percent of the input is never recovered, then we have an economic problem. When that 10 to 15 percent of materials winds up in the atmosphere or in a river, then we have a pollution problem and all of its socio-economic ramifications. Today, this is a problem for commercial manufacturers of wheat gluten and starch around the world.

In a recent issue of *The Southwestern Miller* (1), it was pointed out that vital wheat gluten is primarily used in various specialty products such as diet bread, rye bread, bakery products containing nuts or fruits, and in hamburger and hot dog buns to strengthen the hinge and improve crust characteristics. Many bakers use vital gluten to overcome problems with occasional poorer quality lots of flour.

With the lower protein level of the wheat crop in the Southwest, and with expanded usage of gluten in both bakery and nonbakery items, a hint of a shortage of wheat gluten has been indicated. The A. E. Staley Company has recently announced plans to increase gluten capacity 20 percent (2).

Basically, most gluten is manufactured by the Martin process where wheat flour is kneaded with approximately an equal weight of water to produce a slack dough. The dough is then kneaded gently as additional water is added to wash starch and water solubles away from the gluten. The gluten forms a tough, rubbery, elastic mass of about 30 percent solids. This is carefully dried (3) either by flash drying or redispersing in dilute alkali and spray drying to yield vital gluten of about 70 to 80 percent protein.

In the Martin process and also in the batter process for producing gluten and starch, a total of about 10 pounds of water is used for each pound of flour (4). Nine pounds of that water is rejected from the process as the liquid effluent containing about 1 percent solids. Proteins, pentosans, starch, and minerals are present, along with enzymes and thriving colonies of microorganisms. Decomposition progresses rapidly, and to quote Knight (4) from his book *Wheat Starch and Gluten*, "static pools of the effluent soon become foul, bubbling, and evil smelling." Though these solids might have value in foods or feeds, it is uneconomic to recover them because of their low concentration in the effluent.

At the Western Regional Research Laboratory, we have been working on a wet process for separating protein and starch in wheat flour with the use of less water. This wet process gives essentially complete recovery of flour solids thus obviating any pollution problem. The process is known as the Fesca process (5, 6).

In the Fesca process, it is desired to get a well-dispersed, smooth slurry of flour so that the starch can be directly removed from the slurry by centrifugation while the protein remains suspended.

Figure 1 shows a simple flow diagram for the Fesca process.

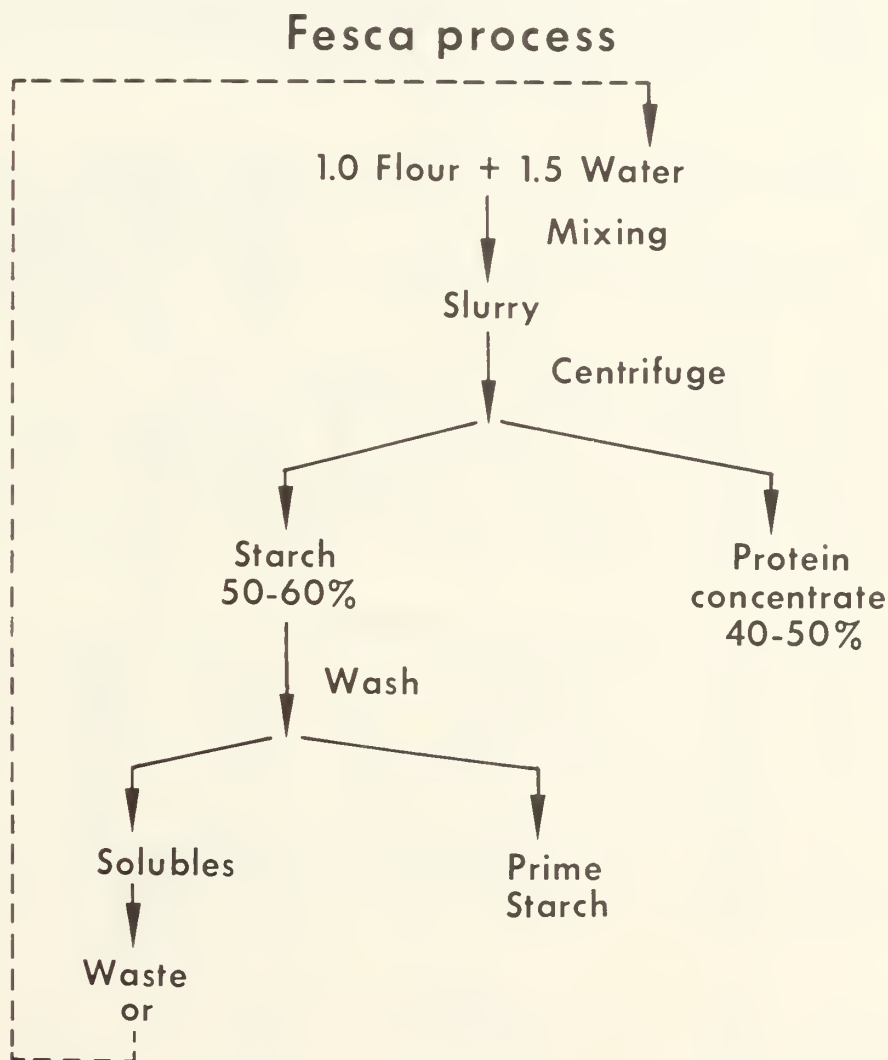


Figure 1.--A simple flow diagram for the Fesca process.

In this process, flour is rapidly and carefully mixed in an optimum amount of water to form a slurry. The slurry is then treated by additional shear to secure maximum release of starch from any remaining structural flour components. Conditions during mixing and shearing are carefully controlled to prevent gluten development. The slurry is pumped to a continuous decanter-type centrifuge and the prime starch is spun out while the liquid protein concentrate is decanted off.

In dry flour, de Ruiter (7) pictured wheat proteins occurring as globular forms, that is, folded into spheres with only a few reactive groups at the surface. As a result, very little cohesion exists between the proteins in individual flour particles. In making a dough, it is necessary to develop intermolecular bonds. Such bonds are more readily created if the protein molecules are unfolded. He believes that the unfolding phenomenon is a direct function of physical stresses during mixing.

If de Ruiter is correct, then the proteins in dry flour are in a condition where they can be segregated or dispersed without having to overcome the forces of intermolecular bonds. It seems, therefore, that nature has given to us the opportunity; all we need to do is find the physical means of mixing water and flour that will prevent the proteins from interacting and forming a dough.

The practical problem of making a flour slurry, then, boils down, in our estimation, to a problem of speed of dispersion because once the flour is dispersed in sufficient water, the system is quite stable and the cohesive forces that play a role in dough development are not present or are of insufficient magnitude to pull the proteins together.

It might be interesting to speculate on why the proteins do not coalesce in a thick slurry. Is it because there is insufficient stress in preparation to unfold the globular protein thus keeping the reactive groups hidden within? Does it have to do with the degree of protein hydration or with the ionic strength of the solution? There is some definite evidence that points to insufficient stress to unfold the globular proteins as a primary reason. In fact, if a flour slurry is subjected to intense shear such as in a Charolette colloid mill or such as being forced through a fine screen at high pressure, one will observe gluten development.

One factor extremely important with respect to the success of the Fesca process is determining the proper ratio of water to flour to be used. If too little water is used, the result is gluten development while too much water destroys the suspendability of the gluten. Each flour has its own optimum water:flour ratio (6).

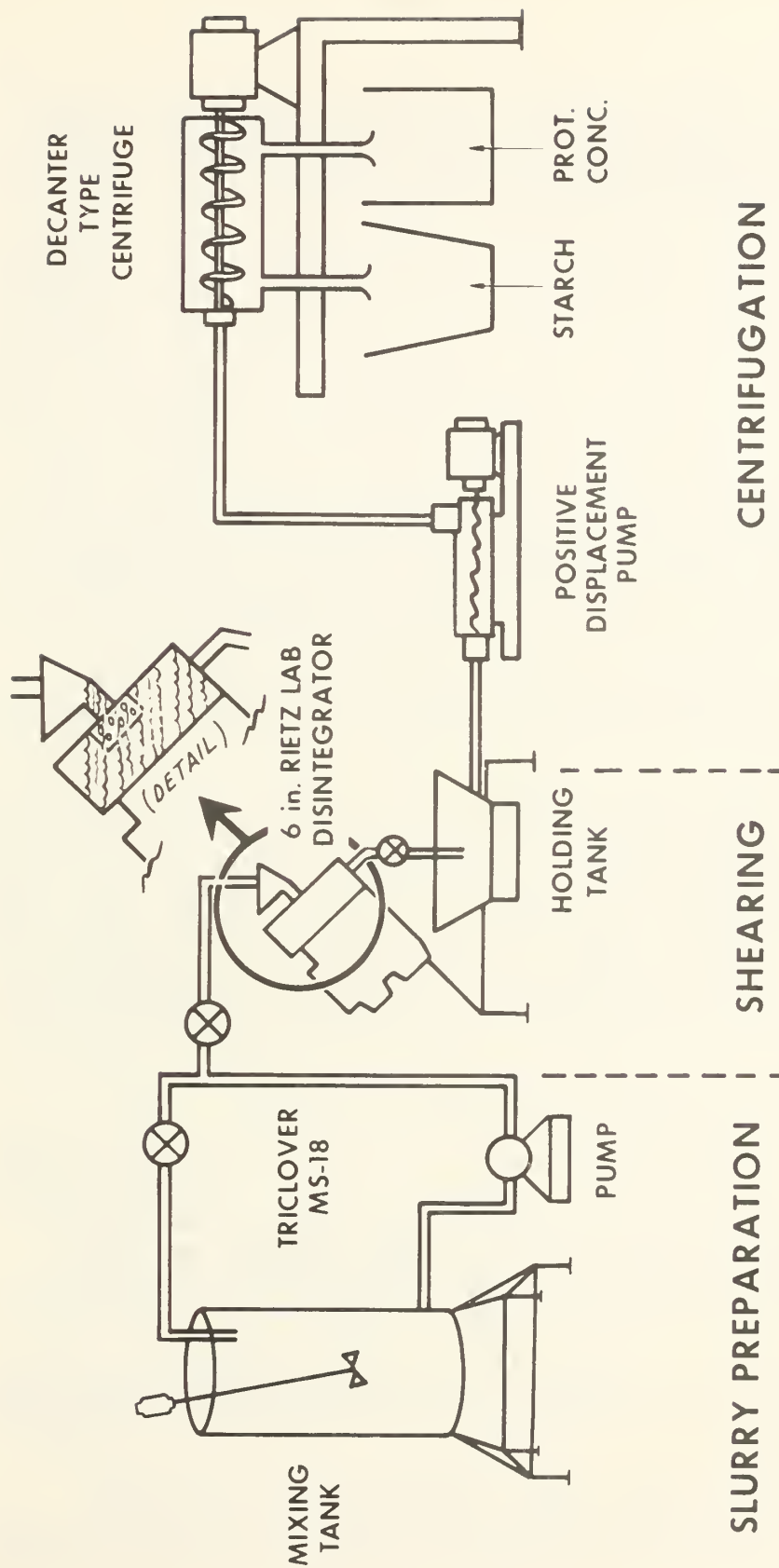


Figure 2.--A schematic diagram of the pilot-plant Fesca process set up at Western Regional Research Laboratory

Figure 2 shows a schematic diagram of the pilot plant Fesca process set up at WRRL. In our pilot plant process, water was placed in a 30-gallon tank and agitated with an air-driven propeller mixer. To aid the mixing, we used a recirculating centrifugal pump. Flour was poured into the vortex of the water as rapidly as possible and the slurry mixed on the order of 5 minutes. This rather crude slurry was then continuously pumped to a Rietz Disintegrator operated at 1,800 r.p.m. The disintegrator is somewhat like a large Waring blender but instead of being a batch process as the Waring blender is, the disintegrator is operated on a continuous through-put basis. The blades of the disintegrator are surrounded with a screen and before the product can escape the blade cavity, it must pass through the screen. In operation, the blades of the disintegrator were flooded with the slurry. Hopefully, the cutting action of the blades and the shearing action of passing through the screen broke down any structural material in the slurry and freed a maximum amount of starch. The sheared slurry was collected in a surge tank and then pumped by a Moyno pump to a Sharples P-600 horizontal, Super D Canter operated at 5,600 r.p.m. or about 2,700 times gravity. Starch at about 56 percent solids was continuously collected from one end of the centrifuge and protein concentrate at 17 to 25 percent solids from the other end.

When using a pastry flour of 7.8 percent protein (moisture-free basis), the process worked extremely well. Using a 1.3 water: flour ratio and operating at a capacity of 300 pounds of dry solids per hour, the yield of dry starch based on flour solids was 78 percent and the yield of dry protein concentrate 22 percent. The starch had a protein content of 0.86 percent (MFB) -- a pretty respectable starch considering that it had not even been washed. One resuspension and centrifugation of the starch reduced its protein content to 0.3 percent. The protein concentrate had a protein content of 33 percent (MFB). This represents a 4.3-fold increase in protein content over the parent flour.

Other components are also concentrated in the protein concentrate. Table 1 gives the analysis of another protein concentrate that was prepared from a soft wheat flour in the laboratory. The flour solubles, which include vitamins, sugars, and lysine-rich proteins are nearly completely retained in the concentrate. This gives the concentrate a nutritional advantage over gluten.

Slurries of a hard red winter wheat, straight grade flour of 14.1 percent protein (MFB) could not be made in the pilot plant process at the natural pH of the flour. It was necessary to add ammonium hydroxide to the water to yield a pH of 8.0 in the final slurry. At this pH, the gluten properties were sufficiently modified and the problem of gluten development was overcome. Using a 1.75 water:flour ratio and operating at a capacity of 180 pounds

Table 1.--Composition (MFB) of a soft wheat flour and a Fesca protein concentrate prepared from it

Item	Soft wheat flour	Fesca protein concentrate
	<u>Percent</u>	<u>Percent</u>
Yield	--	27.7
Protein (N X 5.7)	8.7	28.7
Total sugar	--	6.8
Pentosan	--	5.2
Crude fat	1.05	2.6
Ash	.53	1.2
Fiber	.30	.9

of dry solids per hour, the yield of starch was 63 percent and the yield of protein concentrate 37 percent. The starch had a protein content of 1.5 percent (MFB) and the protein concentrate had a protein content of 38 percent (MFB).

The results of the pilot plant run with the hard wheat flour showed that improvement was needed in the initial preparation of the slurry and in the procedure for fine grinding the wet slurry. To replace the propeller mixer, we have obtained a twin cone blender manufactured by the American Machine and Foundry Company. This device results in extremely rapid dispersion of flour into water (8, 9). This coarse slurry would then immediately be fed to an Oakes mixer (Model No. 8M; E. T. Oakes Corp., Islip, N.Y.). The Oakes mixer is a replacement for the Rietz Disintegrator. We have found the Oakes mixer does an outstanding job in fine grinding the slurry; in fact, we have been able to readily prepare hard wheat flour slurries at considerably lower water:flour ratios and without the use of ammonium hydroxide.

Because of these developments, we are planning to set up a modified pilot plant process in the near future and are confident that we will be able to greatly improve the process for use with hard wheat flours.

Mrs. Maura Bean of our Laboratory has studied the baking value of the Fesca protein concentrate obtained from a hard red spring wheat flour but that is another story. She found the freeze-dried protein concentrate pretty much retained the dough handling and baking properties of the parent flour. She also found the protein concentrate to be useful in fortifying low protein flours to improve their loaf volume.

Fesca protein concentrate has only about half the protein content of commercial vital gluten which runs between 70 to 80 percent. There may be many uses for the Fesca protein concentrate as is but for those uses which would require a higher protein con-

tent, it is possible to further treat the liquid concentrate before drying to recover gum gluten. This might be done in a number of ways. If the liquid concentrate is diluted about 50 percent with water, for example, the gluten coalesces and can be separated. Another method is to subject the liquid concentrate to intense shear which will also cause gluten development and thus its easy recovery. The remaining solubles after gluten recovery would be considerably more concentrated than the effluent from the Martin process and could thus be recovered at less cost. These are areas in which we are still working.

In summary, some advantages of the Fesca process, particularly when compared with the Martin process for gluten washing, are its simplicity and minimum use of water. There are no waste products and thus no pollution problem. The protein concentrate comes from the process as a liquid which makes it easier to handle than the viscoelastic gum gluten of the Martin process. In fact, the protein concentrate can be spray-dried directly. The functional properties of the gluten are not damaged by the process and thus the concentrate remains valuable for use in bakery items.

Because it has now been demonstrated that the Fesca process can be adapted to an extremely simple and continuous operation, the prospects for commercialization are much brighter.

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STARCH AND FLOUR PRODUCTS IN PAPER AND RUBBER

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Research at the Northern Utilization Research and Development Division (NURDD) to find new industrial outlets for cereal products has led to the development of cereal-based reinforcing agents for rubber and cationic flours for use in papermaking. Results from evaluation in the laboratory and small-scale pilot-plant processing studies indicate that prospects for large-scale industrial utilization of these new cereal products are excellent. With further work, particularly field testing and increased promotional efforts, it is believed that widespread industrial acceptance of the products will be realized. The highlights of these two developments are given in this presentation with the story of cereal products in rubber preceding that of cationic flours.

Cereal Products in Rubber

Approximately 5.5 billion pounds of elastomers and an equal amount of reinforcing agents were used in the production of rubber goods in the United States in 1968. The market for reinforcing agents is divided about equally between carbon black and nonblack materials comprised mainly of clays, silicates, and silicas. For effective reinforcement, the particle size of reinforcing agents must be in the 0.02- to 0.2-micron range. The nature of these particles must be such that they can be milled into rubber without aggregating to give a uniform distribution of fine particles in the rubber matrix. Wheat starch granules range in size from 2 to 35 microns, thus, they are much too large to give significant reinforcement.

In the past, numerous attempts by various workers have been made to reinforce rubber by milling in dry starch either in granule form or as a powder obtained from gelatinized starch. Significant reinforcement was never achieved with either form of starch because the original particles were much too large to be effective and were not reduced to the required size during milling into the rubber. The key to obtaining a uniform dispersion of fine starch particles in rubber was discovered in recent studies at NURDD. In essence, it consists of crosslinking a water-soluble starch or starch derivative in a latex emulsion under conditions that give simultaneous precipitation of the starch product and coagulation of the latex. One of the ways in which this is accomplished is shown in figure 1. Starch xanthate with a degree of substitution (D.S.) of 0.08 is mixed into a latex emulsion, then zinc sulfate

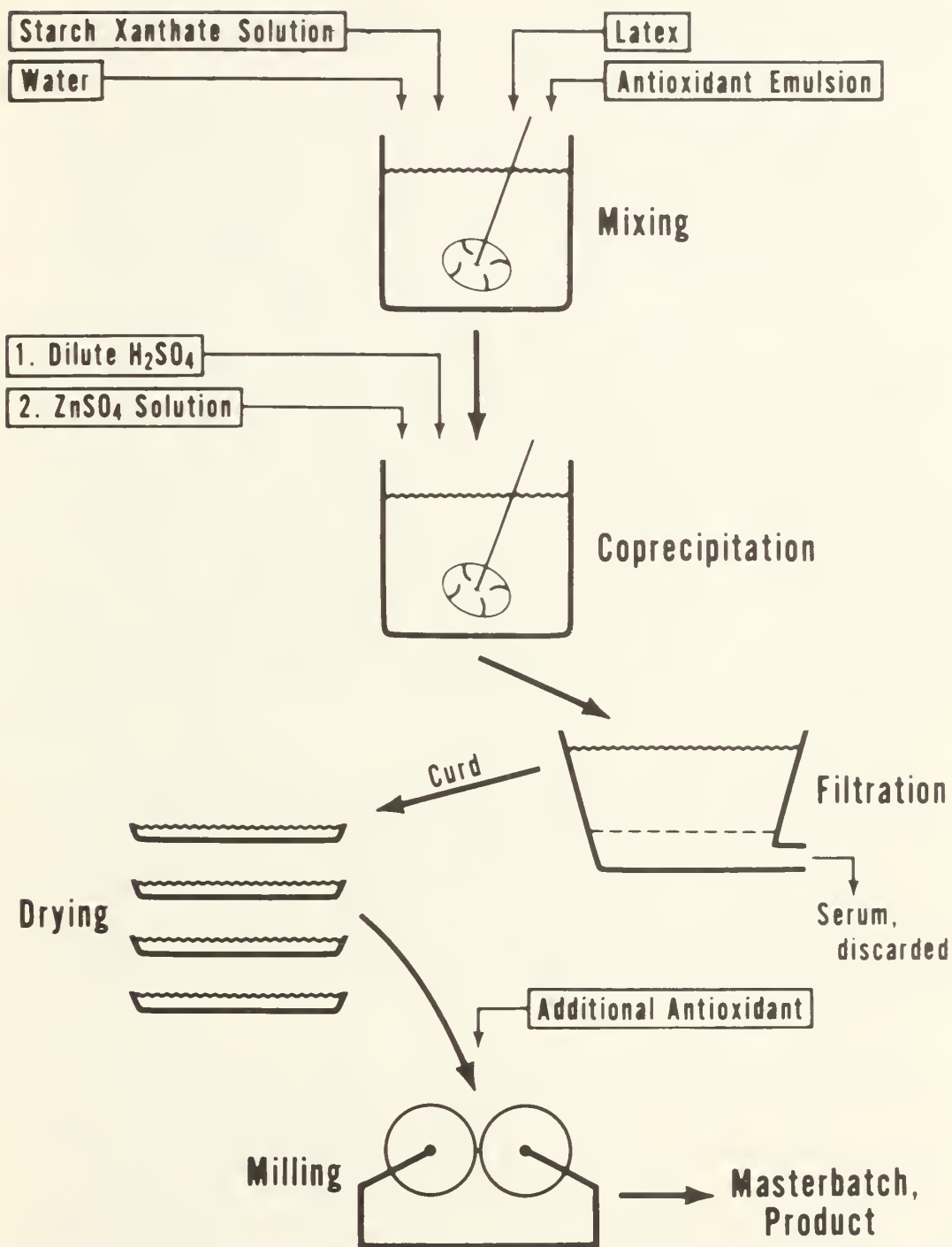


Figure 1.--Flow diagram for incorporating zinc starch xanthate in rubber.

and dilute sulfuric acid are added to give a pH of about 6.5. The zinc insolubilizes the xanthate by forming the crosslinked double salt and the zinc sulfate and acid destabilizes and coagulates the latex. The precipitated curds are filtered off, dried, and milled by conventional methods to give what is called a masterbatch. Vulcanized rubber is made from the masterbatch in the usual manner by adding standard curing agents followed by the application of heat and pressure in an appropriate mold. In the dried curds, the zinc starch xanthate exists as an external phase surrounding the latex particles. During milling a phase-reversal occurs to give a uniform dispersion of very fine particles of zinc starch xanthate in a continuous phase of rubber. Since most rubber is produced in latex form, the above process is widely applicable. In a variation of the above process, the starch xanthate-latex mixture is treated with sodium nitrate and acid. This treatment produces nitrous acid which oxidatively couples the xanthate to give a crosslinked product called xanthide. In other variations of the process (shown in fig. 1), 4.6 parts resorcinol and 3.4 parts formaldehyde by weight, based on starch xanthate, are added to the xanthate-latex mixture. The resulting dispersion is stirred at room temperature for 1/2 hour, then the xanthate-resorcinol mixture is treated with either zinc sulfate or nitrous acid to achieve crosslinking and insolubilization. Unxanthated starch can be used in conjunction with resorcinol and formaldehyde in which case precipitation of the starch product and coagulation of latex is achieved by addition of ferric sulfate.

In rubber technology and throughout this presentation, loading levels are expressed as parts reinforcing agent per 100 parts of rubber by weight and are abbreviated phr. This is somewhat confusing to the uninitiated because phr actually refers to the parts of reinforcing agents per 100 parts of unadulterated elastomeric polymer rather than to the parts of reinforcing agent per 100 parts of the final rubber composition. The phr figures are all based on the amount of cereal raw material rather than their derivatives because there is no practical method for determining the crosslinked products.

Both zinc starch xanthate and starch xanthide give light straw-colored semitransparent rubber, which can be converted readily to white rubber with the addition of much less of the costly zinc and titanium oxides than is needed in rubber reinforced with clays. In addition, these two starch products give stronger white rubber than can be achieved with common white clays. Comparatively costly pyrogenic silicas or treated clays are needed in white rubber to meet the strength properties of white rubber reinforced with zinc starch xanthate or starch xanthide. These two starch-based reinforcing agents also have other advantages. Rubber reinforced with them can be treated with dyes to give semitransparent, brightly

colored rubber. When clay is incorporated along with the dyes, the colored rubbers are opaque. Rubbers reinforced with starch xanthates and xanthides are much lighter weight rubbers than clay-loaded rubbers because the starch products are much less dense than clay. This is an important factor in footwear and other applications. It is also an important economic factor because a light-weight rubber composition will yield a greater volume of consumer goods per pound than a dense rubber. Because of their comparatively low density and superior performance, starch-based reinforcing agents are judged to be competitive with most reinforcing clays and related products even though the per pound cost of the starch products may be higher. This judgment is based on use of starch xanthate produced in-house or supplied in an over-the-fence operation at a cost of no more than 8 cents per pound on a dry basis. The 8-cent figure appears to be reasonable because studies at NURDD on the production of cereal xanthates show that xanthates with a D.S. of 0.08 can be produced on a 50-ton per day basis at a cost of 1.7 cents per pound above the cost of the cereal raw material. Based on the 8-cent cost figure, the cereal-based reinforcing agents are competitive with medium-grade carbon blacks. The cereal products are less expensive than highly reinforced carbon blacks used in tire treads but do not give the required strength properties for quality tread stock. Before turning to the test data on rubber reinforced with starch products, it should be mentioned that equally effective products of the same nature have been made from cereal flours.

The effect of zinc starch xanthate on the tensile strength, tensile stress, and ultimate elongation of styrene-butadiene rubber (SBR) is shown in figure 2. Tensile strength increases up to about 25 phr xanthate then decreases as more xanthate is added. The tensile stress at 300-percent elongation is merely the force in pounds per square inch required to stretch the rubber 300 percent beyond its original length. The ultimate elongation shows how far the rubber stretches beyond its original length at the breaking point. Up to 25 phr starch xanthate, the above properties are similar to those of rubber loaded with equal amounts of medium-grade carbon black. Although stronger rubber may be made by adding more carbon black, the zinc starch xanthate-reinforced rubber is strong enough for many applications.

Comparative data on reinforcement of SBR with starch and flour products are given in table 1. The figures given are average values from a series of runs with SBR and cereal xanthates. Loading levels were 30 phr and 45 phr and two methods of cross-linking, zinc salt formation and oxidative coupling, were used with each cereal xanthate at each loading level. The data show that there is no significant difference between the performance of the starch- and flour-based reinforcing agents.

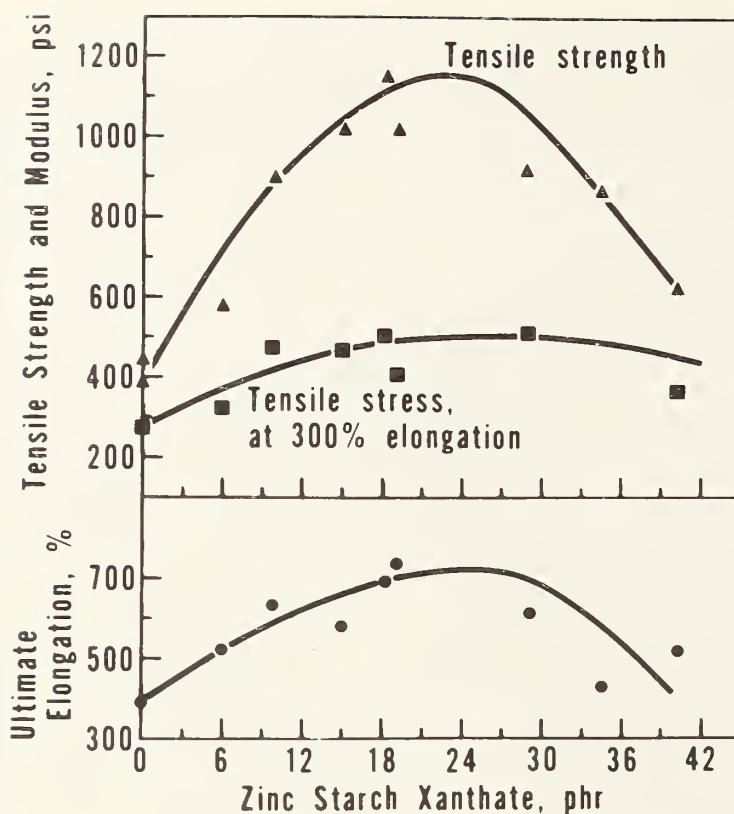


Figure 2.--Effect of zinc xanthate loading levels on properties of SBR rubber.

Table 1.--Comparison of cereal flours with starch as rubber reinforcing agents

Vulcanizate properties	Cereal starch	Cereal flour ^{1/}	Least significant difference
Hardness, Shore A	65.0	65.5	2.5
Rebound resilience, percent	52.8	51.5	2.4
Tensile strength, p.s.i.	1,498	1,398	314
Tear strength, pi	180	178	22
Abrasion resistance	100	98	0.15
Volume swelling in H ₂ O, percent	7.05	6.50	1.7

^{1/} No significant difference between yellow corn flour, soft wheat flour and hard wheat flour.

The effect of starch-resorcinol-formaldehyde resin derived from unmodified corn starch on properties of SBR vulcanizates is given in figure 3.

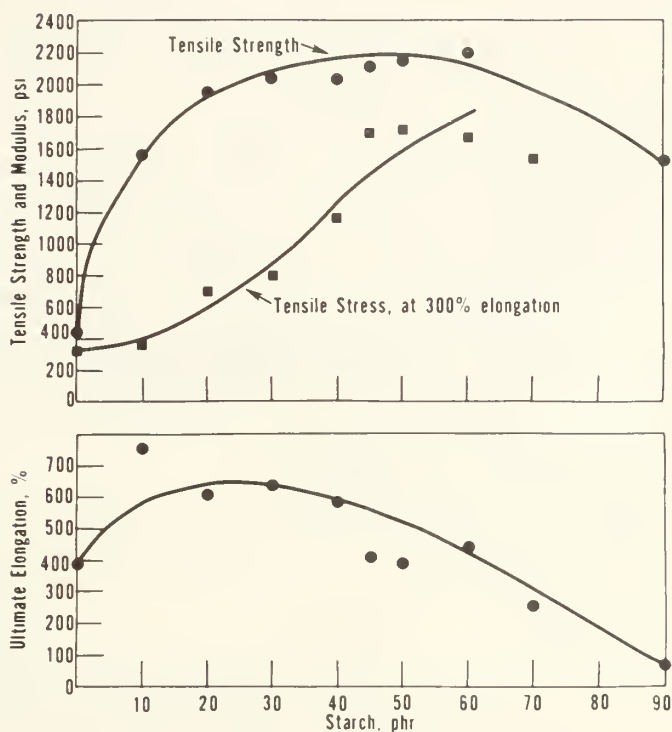


Figure 3.--Effect of starch resin on tensile properties of SBR 2105 vulcanizates (6-percent resorcinol based on starch).

The resin and latex were coprecipitated with ferric sulfate. The vulcanizates or cured rubbers obtained from such coprecipitates are dark mahogany colored but considerably stronger than SBR reinforced with either zinc starch xanthate or starch xanthide. Quantitative recoveries are not easily achieved when unmodified starch is used with resorcinol and formaldehyde, but this problem might be solved with further study. Substitution of starch xanthate for unmodified starch makes quantitative recoveries by practical means easy and the same or slightly higher strength properties are realized.

In research and development studies conducted under contract for the Department at the Institute of Polymer Science, Akron University, it was discovered that extrusion drying of the cereal product-elastomer coprecipitates instead of oven drying led to greatly increased strength properties in the vulcanized rubbers. The effect of extrusion drying on strength properties of SBR

reinforced with starch xanthide is quite apparent in figure 4. The loading level for maximum tensile and elongation was raised from about 25 phr to 50 phr. This is a desirable feature because reinforcing agents are cheaper than latex. Also, about a 50-percent increase in maximum tensile strength was realized. The

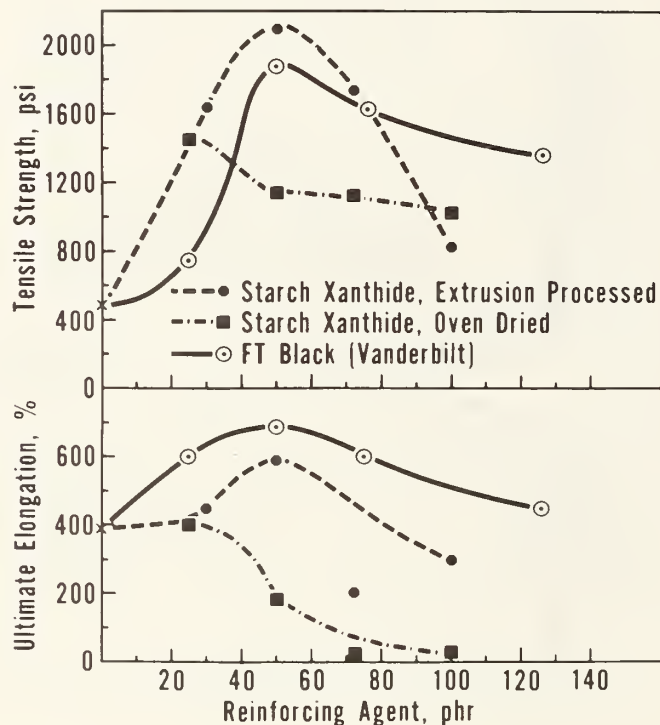


Figure 4.--Starch xanthide compared with FT black as reinforcing agent in SBR 1500.

new tensile maximum of 2,150 p.s.i. greatly increases the number of potential applications where cereal-reinforced rubber could be used. Extrusion drying also eliminated stress-whitening, reduced sensitivity to water, and improved such rubbery properties as resilience, stretch, and flexibility. Much the same improvements in rubber reinforced with zinc starch xanthate were obtained by extrusion drying. Tensile strength of rubber reinforced with starch resins was relatively high in the oven-dried rubbers, therefore, extrusion drying gave only moderate increases in tensile strength. However, other properties of this type of rubber were improved by extrusion drying to about the same extent noted for the other cereal-reinforced rubbers. Microscopic examination of oven-dried and extrusion-dried rubbers showed that starch particles were finer and more uniformly distributed in the latter. Such a state of dispersion is known to coincide with

good strength properties and was probably brought about by high shear associated with extrusion at a point when moisture content was ideal for fragmentation of starch particles.

Extensive studies were conducted at Akron University to determine what areas cereal-reinforced rubbers were best suited for. This included formulation with extender oils, plasticizers, and other commonly used rubber additives as well as pilot-plant studies to determine processing characteristics and costs. These studies show that the cereal-reinforced rubbers developed to date have best commercial opportunities as general-purpose molding compounds, oil-resistant rubbers, and shoe sole rubbers. The good matches between the formulated cereal compositions and their commercial counterparts are shown in tables 2, 3, and 4. All of

Table 2.--SBR general purpose molding rubber
[Starch vs. carbon black reinforced]

Property	Rubber	
	Standard commercial FEF Black-SBR	Starch xanthide resorcinol formaldehyde-SBR ^{1/}
Hardness, Shore A	72	69
Tensile strength, p.s.i.	2,420	2,250
Rebound resilience, percent	29	46
Abrasion resistance	100	460
Water swelling, percent	7.0	6.6
Benzene swelling, percent	210	194

^{1/} 50 parts starch product per 100 parts rubber.

Table 3.--SBR shoe sole rubber
[Starch vs. silica + resin reinforced]

Property	Rubber	
	Silica and resin-SBR	Starch xanthide-SBR ^{1/}
Hardness, Shore A	92	90
Tensile strength, p.s.i.	1,500	2,250
Rebound resilience, percent	15	35
Abrasion resistance	100	134
Water swelling, percent	-4.0	-3.7
Benzene swelling, percent	380	257

^{1/} 50 parts starch xanthide per 100 parts rubber.

Table 4.--NBR^{1/} oil resistant rubber
[Starch vs. carbon black reinforced]

Property	Rubber	
	Standard commercial fuel hose [SRF Black-NBR]	Starch xanthide resorcinol formaldehyde-NBR ^{2/}
Hardness, Shore A	64	70
Tensile strength, p.s.i.	2,650	2,650
Rebound resilience, percent	18	24
Tear strength, pi	247	178
Water swelling, percent	6.5	6.0
Benzene swelling, percent	127	102

^{1/} NBR = Nitrile-butadiene rubber.

^{2/} 50 parts starch product per 100 parts rubber.

the cereal-rubber masterbatches were extrusion dried. The only figures in these tables that need some comment are those for volume swelling in water and the one on abrasion resistance of starch-reinforced, general-purpose molding rubber.

The swelling figures are unexpectedly low for rubber reinforced with a hydrophilic starch product. No doubt the starch particles are embedded in and completely surrounded by the continuous rubber phase and so are not accessible to water. The abrasion resistance of the general-purpose molding rubber reinforced with starch resin (table 2) is exceptionally good. Not all starch-reinforced rubbers have such high abrasion resistance, but several have shown significantly higher abrasion resistance than their commercial counterparts. However, some of the cereal-reinforced rubbers are less resistant to abrasion than the reference rubbers.

In accelerated heat-aging tests (data not shown), the starch-reinforced rubbers with the exception of the oil resistant one held up as well as the reference rubbers. Tensile strength in the starch-reinforced oil resistant rubber declined about 14 percent more than it did in the reference rubber but was well within acceptable limits.

Based on properties and costs, the above three types of starch-reinforced rubbers are judged to be competitive with their commercial counterparts which dominate a large part of the nontire rubber market. In addition to tread rubber, about six or seven other types of rubber are used in making a quality tire. Although some of the rubbers reinforced with starch products are strong enough to meet all but quality tread requirements, many other

properties such as aging characteristics, fatigue properties, and adhesiveness need to be determined before the potential role of cereal-reinforced rubbers as tire components can be assessed. Nonetheless, it is felt that the rubber industry affords good opportunity for utilization of vast amounts of cereal products in view of the results achieved thus far.

Cationic Flours

Cationic starches are used extensively as wet-end additives in papermaking to increase strength properties and improve filler retention in quality papers. It is estimated that the market for cationic wet-end additives could be increased by 100 million pounds per year if products were developed which were sufficiently lower (about 35 percent) in cost to permit them to be used more widely in coarse papers. Cereal flours, being lower in cost than starch, afford an opportunity for such development. However, no flour products approaching the performance of cationic starches have appeared on the market. Cereal flours do not respond well to the cationizing reagents commonly used to modify starch. However, in an extensive study of flour modification, we found that treatment of cereal flours with a small amount of ethylenimine produced cationic products which in handsheet and pilot-plant paper machine evaluation performed as well as or better than premium-grade cationic starches.

The possible reactions which occur between ethylenimine and the components of flour are shown in figure 5.

Conditions for preparing cationic flours are outlined in figure 6.

One hundred parts of flour with normal moisture content are treated with three parts of ethylenimine by weight and the mixture blended in a closed reactor for 4 hours at 60°C. The reaction mixture is then acidified by spraying in dilute hydrochloric acid while mixing is continued. The slightly acidic aminoethylated flour is a dry, free-flowing powder when removed from the reactor and is quite stable to storage under ordinary conditions. Although ethylenimine is volatile and toxic, it can be handled without difficulty if precautions given by the manufacturer are followed. On acidification, any unreacted ethylenimine is converted to its polymer (polyethylenimine), consequently, the modified flour can be handled without taking any unusual precautions.

Evaluation of aminoethyl flour before and after removal of polyethylenimine by extraction has shown that its presence neither adds to nor detracts from the performance of the flour, therefore, it is not removed in our process. The solubility or dispersibility

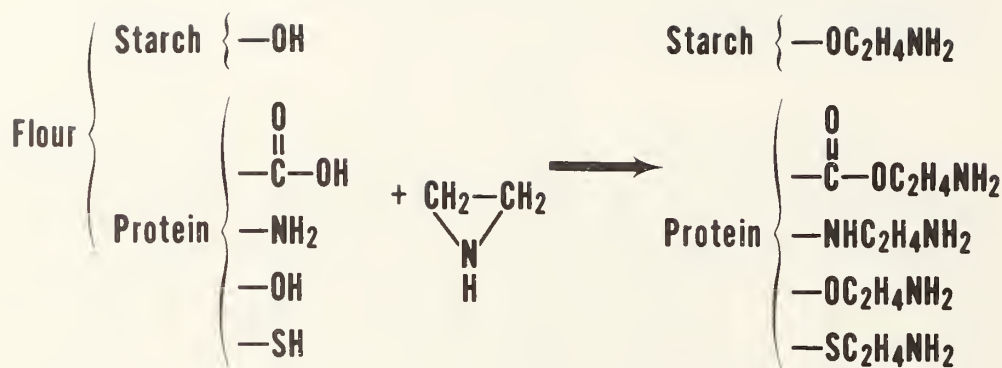


Figure 5.--Reaction of ethylenimine and functional groups of cereal products components.

Mix for 4 hours at 60°C
Flour + Ethylenimine
(100 Parts) (3 Parts)
 Then **↓** **Acidify**
Cationic Flour
(101.5 Parts)
 +
Polyethylenimine
(1.5 Parts)

Figure 6.--Reaction conditions for preparation of cationic flours.

in water of both the starch and protein components of flour is increased considerably by treatment of flour with ethylenimine indicating that both components are modified. To provide information on the role of protein in the performance of aminoethylated flours, starch was aminoethylated under the same conditions used for the flours.

The sigma blade mixer used in preparing aminoethyl flours on a laboratory scale is shown in figure 7.

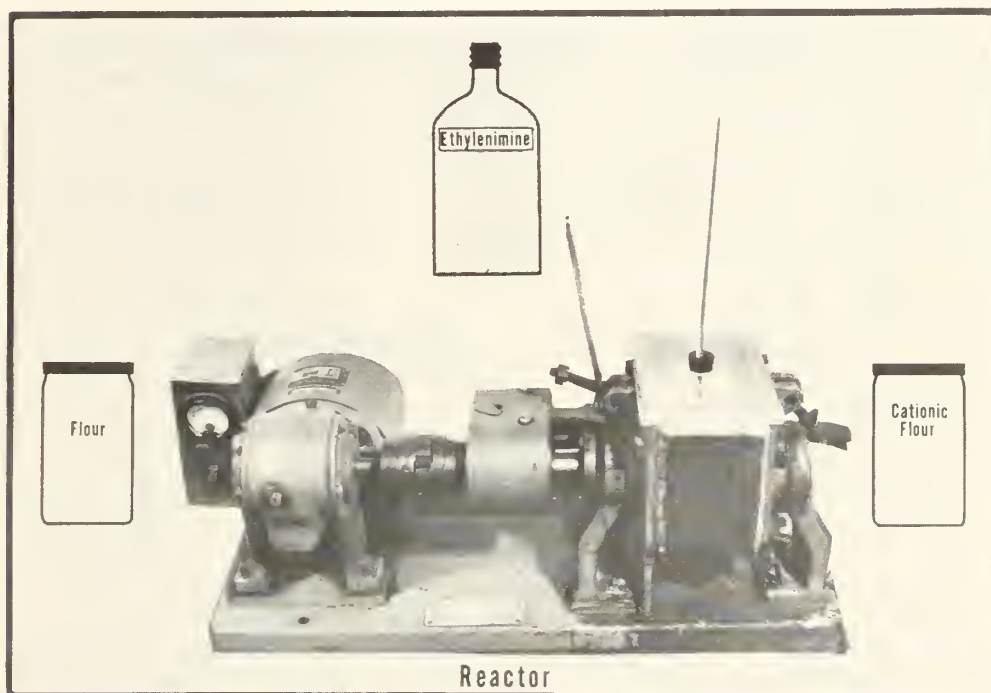


Figure 7.--One-quart sigma blade mixer used in preparation of cationic flours in the laboratory.

The mixer is jacketed to provide for circulation of a temperature-controlling medium. The gasketed, clear, plastic cover which can be bolted on tightly has a small hole in the center which serves for both introduction of reagent and acid, and insertion of a thermometer through a tight-fitting rubber stopper.

For evaluation in papermaking, aminoethylated flours, aminoethylated starch, and a premium-quality commercial cationic starch were dispersed in cold water at a concentration of 2 percent and stirred while live steam was introduced to raise the temperature to 90°C. Pasting was continued for an additional 1/2 hour at 90°C. then the pastes were diluted to give either 1

percent or 1/2 percent dispersions for introduction to pulp furnishes. In machine runs all dispersions of flour and starch products were introduced at the fan pump.

In handsheet evaluations, cationic flours derived from corn, wheat, and sorghum flours were all as effective as the reference cationic starches in improving dry-strength properties of paper when used as an internal size. Performance of the cationic flour as pigment retention aids was equally good. Accordingly, extensive evaluations were carried out on our 32-inch pilot-plant paper machine.

Strength improvements obtained in unbleached bag paper in a series of 1-hour machine runs with cationic flours and the reference starches are summarized in figure 8. In tensile strength

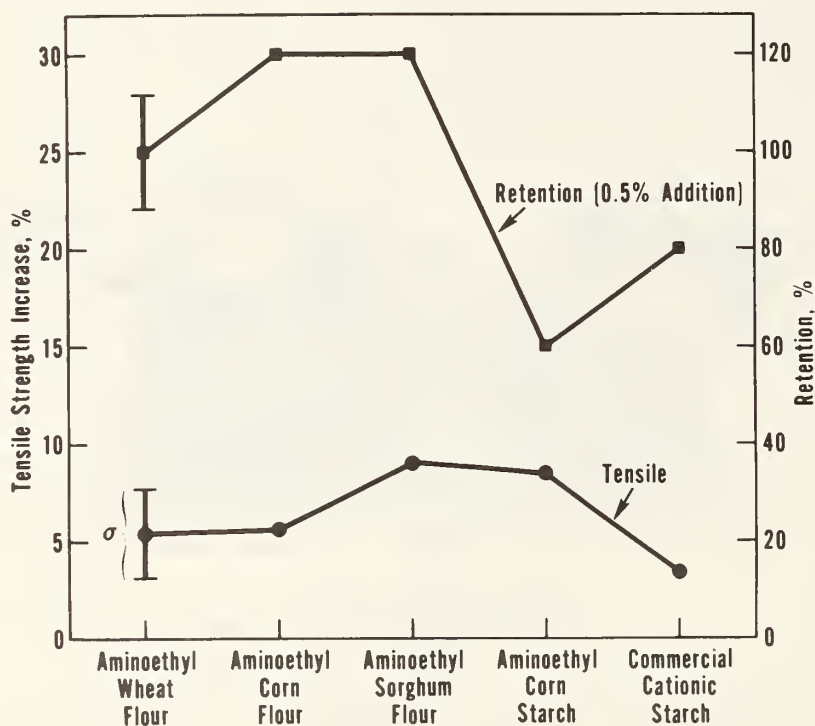


Figure 8.--Tensile strength improvement and retention of cationic cereal derivatives at the 0.5-percent level of addition to sized bag paper. The variation about the mean values, at the 67-percent confidence level, is shown in the figures as " σ ."

improvement there is no significant difference between any of the products. However, retention of the cationic flours in paper was significantly higher than that of the reference starches.

The utility of cationic flours as strength improvers and as retention aids for clay filler in filled bond paper was determined in a series of machine runs. The clay was added to the pulp furnish at the 10-percent level based on dry weight of pulp. Results of the machine runs are summarized in figure 9 and show that there is no significant difference between the

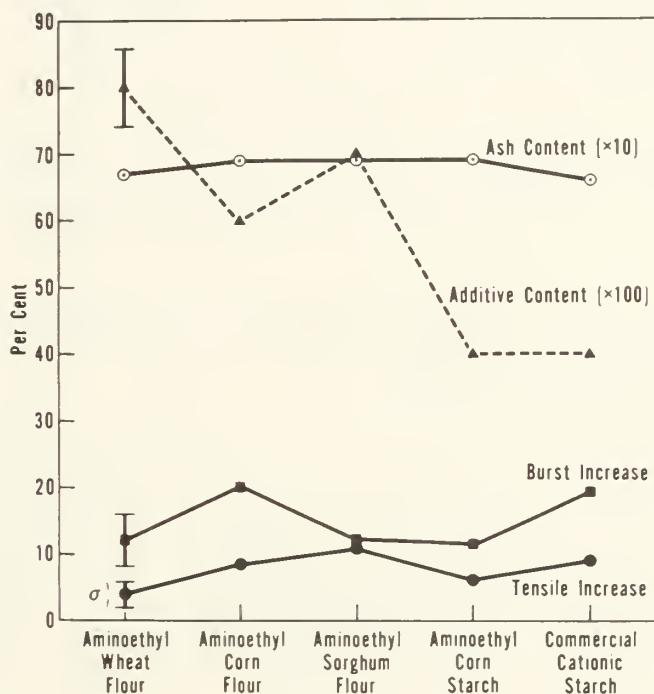


Figure 9.--Strength improvement, ash content, and retention of cationic cereal derivatives at the 0.75-percent level of addition to filled-bond paper. Clay filler was added at the 10-percent level based on the weight of oven dry pulp. The variation about the mean values, at the 67-percent confidence level, is shown in the figures as " σ ."

test flours and the reference starches as far as improvements in tensile and bursting strengths of the paper are concerned. Clay-filler retention was the same for all additives but again the cationic flours were retained to a significantly higher degree than the reference starches.

To determine whether use of cationic flours led to protein buildup in the white water, a 4-hour run was made and the percent nitrogen in the white water solids as a function of running time was determined. The results of this study are given in figure 10

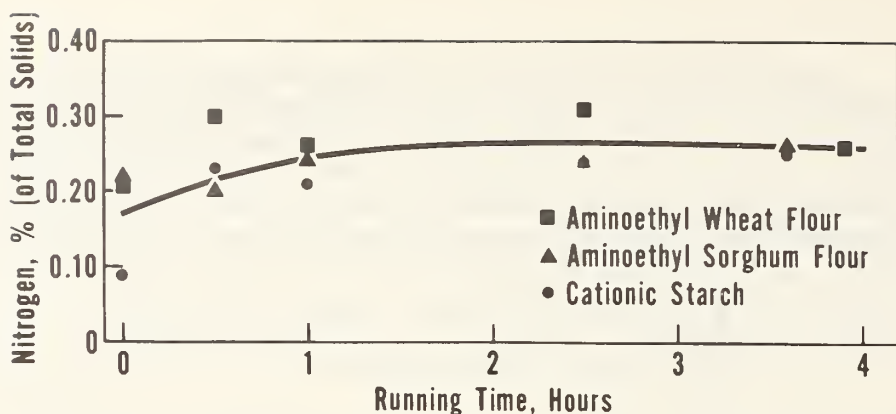


Figure 10.--White water nitrogen content in filled-bond paper trials with cationic products added at the 0.75-percent level based on the weight of oven-dry pulp.

and show that after a slight increase in nitrogen content during the first hour equilibrium is reached. Thus, there need be no concern about protein buildup.

The laboratory process for preparing aminoethylated flours has been scaled up to 40-pound runs in the pilot plant without difficulty. A cost estimate for producing aminoethylated flours has been made by our Engineering and Development Laboratory. The estimate includes reagents, utilities, labor, supervision, maintenance, fixed charges, miscellaneous factory supplies and expenses, charges on working capital, and general plant overhead. It does not include the cost of flour, selling costs, administrative expenses, interest on investment, profit, and taxes. On the basis of a plant producing 20 tons per day (300-day year) and the current cost of ethylenimine (\$0.85 per lb.) the cost (excluding flour) is \$0.04 per pound. With \$0.04 per pound flour, the cost for making aminoethylated flour would be only \$0.08 per pound. This "cost-to-make" figure would suggest a probable selling price of about \$0.10 to \$0.12 per pound as compared with an average selling price of \$0.18 per pound for cationic starches of comparable quality. Thus, the potential for large-scale use of cationic flours in papermaking appears excellent. However, evidence of successful mill trials needs to be provided and a number of mill trials have been scheduled.

STARCH PRODUCTS FOR PLASTICS AND FLOCCULANTS

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Starch is a natural polymer of widespread occurrence and often found in high concentration in seeds, roots, and tubers. Chemically, starch is synthesized by the plant from the simple sugar glucose. As one molecule of glucose is combined with another a molecule of water is eliminated. The final starch molecules contain from a few thousand to a hundred thousand or more glucose units. Starch is called a polymer because it is comprised of many like units chemically united to form large molecules.

The industrial use of starch rests primarily upon its chemical, physical, and biochemical properties. However, without the availability of starch and at a low price, we would not be talking about it here today. Over the years man has modified starch by a wide variety of treatments to obtain products having special properties to serve an ever-growing number of new and useful applications.

At the Northern Regional Research Laboratory in Peoria, Ill., we are actively engaged in a continuous search to develop new products from cereal grain starches and flours. For many products it is not important whether the starch is from corn, wheat, or sorghum. In some cases it is found that cereal flours can be used for the same purposes as starch.

It is my privilege to describe two areas of our research and recent developments on new products from starch.

Starch in Plastics

Starch is first broken down to simple units and then recombined with nonstarch chemicals to produce plastics and related chemical products.

Our approach to utilizing starch in this instance depends upon the chemical treatment of starch with ethylene glycol (fig. 1). Ethylene glycol is the major ingredient in permanent-type antifreeze. When starch and ethylene glycol are heated together in the presence of an acid catalyst, a mixture of sugar derivatives is obtained which is known as glycosides. This low-cost glycoside mixture can be modified with various chemicals to obtain important ingredients for plastics, coatings, and detergents.

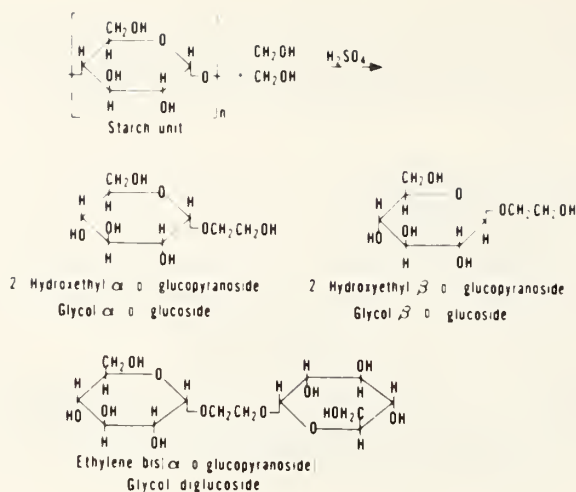


Figure 1.--Reactions of starch with ethylene glycol to form glycol glucosides

We have successfully modified the starch-derived glycosides so that they can be used in making two types of plastics. One type is rigid urethane foam. To modify these starch-derived glycosides for use in urethane foam, we first react them with propylene oxide (a petroleum-based product) according to the equation shown in figure 2.

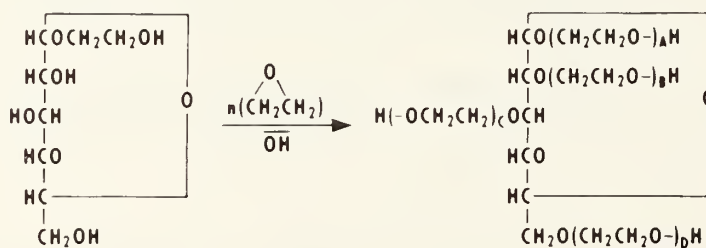


Figure 2.--Modification of glycol glucosides by reaction with propylene oxide

Generally, it is best to add 6.5 moles, or 1.8 parts by weight, of propylene oxide for each mole or part of glycoside. Rigid urethane foam is then prepared by combining this polyether with other components as shown in table 1.

Table 1.--Typical foam formulations

Table 1. Typical Foam Formulations		
Item	Percent ^{1/}	
Component A		
Glycoside polyether (OH, 416)	39.31	52.71
Dibutyl tin dilaurate	0.06	0.06
Dimethylethanol amine	0.49	0.49
Dabco 33	0.48	0.48
Surfactant	0.98	0.98
Fyrol 6	7.94	--
Blowing agent (Freon 11) 16.67 percent		
Component B		
Crude TDI	--	45.28
PAPI	50.74	--

^{1/} Exclusive of blowing agent

The starch-derived material is mixed with a catalyst to control the speed of foaming, a surfactant to control the size of cells or bubbles, a fire-retardant agent (if desired), a blowing agent which causes the foaming, and finally an isocyanate. The liquid formulation expands 40 times in volume and within 1 minute becomes a solid foam. We have tested this foam extensively and have found it to be an effective material for insulating against both heat and cold.

This year about 200 million pounds are being produced in the United States--most of which is used for insulation of refrigerators, houses, storage tanks, and cold-storage warehouses. Foam may be applied as sheets or sprayed onto surfaces where surface texture is not important.

Our process has not been commercialized. It has been successfully scaled to pilot-plant quantities. However, sorbitol and methyl glucoside, which also are made from starch, are being utilized in commercial urethane foam. According to one raw material producer, our process of starting with starch lends itself best to a 10-million-pound-per-year or larger plant. He expects that our process will be commercialized as production of urethane foam increases during the next 2 to 5 years.

We have received more than 800 requests for information on either our process or techniques used to evaluate raw materials--attesting to the interest in this foam project. We believe this study has stimulated additional interest in the use and production of urethane foam and that in a few years the process will utilize several million pounds of starch.

We have made a second type of urethane plastic in the form of a floor tile, which shows some promise in utilizing starch-derived glycosides. Chemically, it is much the same as urethane foam but made without the blowing agent. One added feature, however, is that large amounts of starch may be added as a filler to make this plastic product. The tile product contains about 50 percent starch as filler plus a smaller amount of starch which was used to make the urethane resin. A representation of the resin preparation is shown in figure 3.

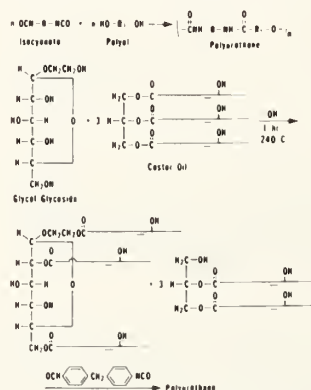


Figure 3.--Reactions in the preparation of a polyurethane resin.

Various amounts of starch-derived glycosides were mixed with castor oil and an alkaline catalyst and heated at 240° C for 1 hour. The resin was then mixed with a polyisocyanate and catalyst and subjected to heat and pressure molding for 10 to 15 minutes. The plastic is tough, chemically resistant, clear, and transparent. Dyes may be incorporated to give tiles of any desired color.

When isocyanate in excess of that required for the polyol is added, polymers are produced with terminal-NCO groups. A significant number of these NCO groups are believed to react with hydroxyls of the starch when a mixture of the urethane polymer and starch is subjected to molding. Presumably, starch particles and the urethane inter-react to form crosslinked structures. Analysis shows a decrease in excess isocyanate when starch is added, and the plastics are generally harder, stronger, and more resistant to heat. The starch-filled plastics are not affected by water and acid at room temperature; however, they lose some strength when allowed to stand in hot water for 1 week. Since reporting this study in April, we have received inquiries from more than 75 organizations.

In addition to plastics, starch-derived glycosides can be used to synthesize surfactants which are the basic active components of detergents. First, (fig. 4) the starch-derived glycosides are reacted with about 20 moles ethylene oxide and

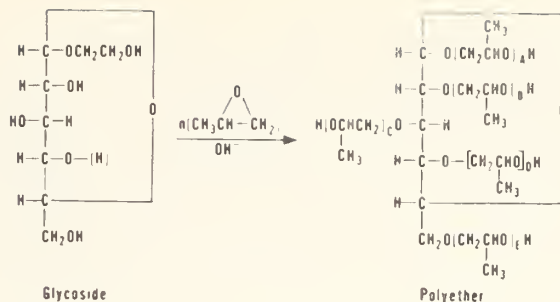


Figure 4.--Modification of glycol glucosides by reaction with ethylene oxide.

then esterified as (fig. 5) with 1 or 2 moles fatty acid.

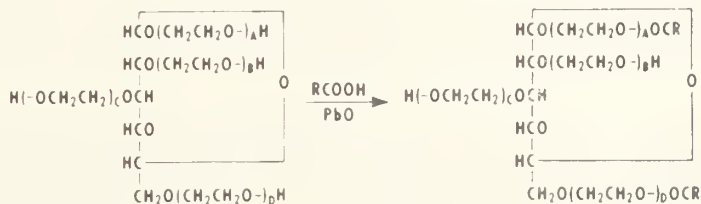


Figure 5.--Preparation of surfactants by esterification of starch-derived polyethers.

Preparation and evaluation of these surfactants will be completed early in 1970. Finally, we have found that glycosides from starch can be used to make alkyd resins. Alkyds are the basic component of most household and industrial paints and enamels.

In summary, these starch-derived glycosides have a variety of potential applications in products that could utilize starch from several million bushels of grain.

Flocculants

We are studying the combination of the natural polymer starch with synthetically produced polymers to make a graft copolymer. The resulting copolymers have a combination of some of the properties of starch and some of those of the grafted product. In many cases, the copolymer has properties not common to either of the two parts alone. The schematic structure of a copolymer is seen in figure 6.

Starch is activated or made reactive by means of gamma rays or an electron beam, after which a chemical monomer is added and allowed to react (fig. 6). Addition of the non-starch monomer chemical (M) to the activated starch results in the grafting of new polymer chains to the starch molecules. The conditions of synthesis may be varied as to both frequency and size of the grafted chains. Much of our past and current

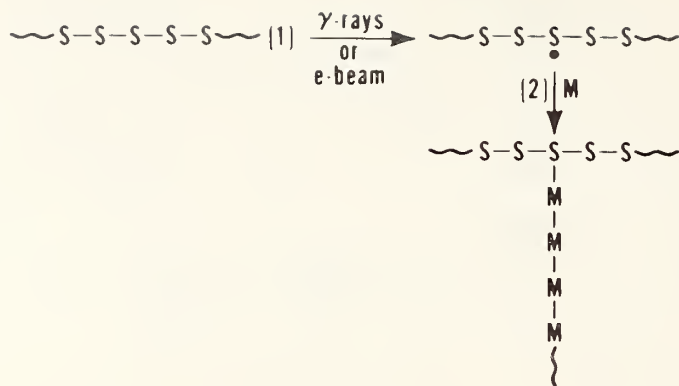


Figure 6.--Representation of the formation of a graft copolymer.

effort is somewhat basic in approach so far as getting a picture of how reaction conditions influence the nature of the final product. Other studies are directed toward determining more exactly what the architecture of a given copolymer is and how the structure of the graft copolymer leads to observed chemical and physical properties.

A large share of our involvement is the evaluation of graft copolymers for performance in specific probable end-use applications. After having prepared several score of starch graft copolymers, we are now able to see good promise for some of the new products (fig. 7).

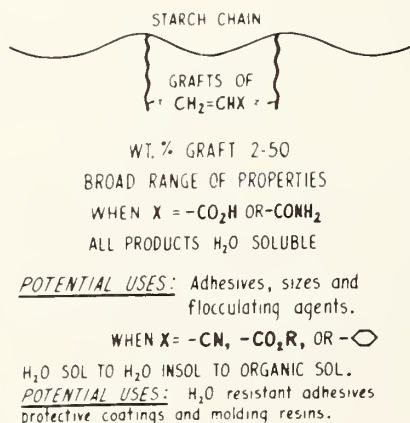


Figure 7.--Range of properties obtainable in graft copolymers of starch.

We have concentrated recent efforts on the preparation of water-soluble graft copolymers. Such materials are necessary if applications are to be found for the flocculation of unwanted, finely divided solids in minerals, industrial and municipal wastes and the dewatering of wanted concentrates in mineral and other industrial recovery systems. The same materials that act as flocculants have been found to serve also as retention aids of clay in paper products.

One of the copolymers studied most is starch-polyacrylonitrile. When partially hydrolyzed, it yields a material that exhibits unusually high viscosity at low concentrations in comparison with other water-soluble gums. Such materials are of value in the secondary recovery of oil, in prevention of fluid loss in drilling muds, and in many preparations where thickeners are required in aqueous systems.

Several graft copolymers have shown good flocculation of silica in aqueous suspensions. The copolymers of starch and poly(2-hydroxy-3-methacryloyloxypropyltrimethylammonium chloride) approached and in some cases exceeded presently used products in flocculating ability toward silica and iron ore.

Sufficient evidence is now at hand to strongly indicate the need to prepare sufficient quantities of the copolymers for demonstration and trials by industry. Plans have been prepared for activating this phase of work in the next year.

In summary, we believe that graft copolymers of starch with 2 to 50 percent, by weight, of grafted nonstarch offer one of the most promising routes now available for expanded use of starch. The graft copolymers are versatile because they can act as flocculants, thickeners, sizes, beneficiants in ore and mineral treatments, clarifiers of waste waters and sewage, and as retention aids and strengtheners in papermaking. With high possibilities in so many industries--mining, papermaking, industrial and municipal waste treatment, petroleum production, textile manufacture, and a large number of perhaps smaller volume uses such as coatings and inks and chemical specialties--we look forward to a wholly new array of industrial starch-copolymer products.

PROSPECTS FOR NONFOOD USES OF GLUTEN

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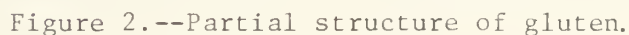
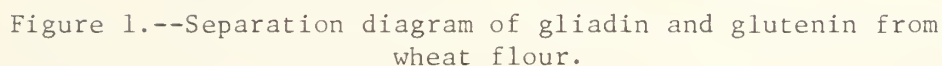
Wheat gluten today has few nonfood applications. Such proteins as silk fibroin, casein, and to a lesser extent zein, now utilized, possess unique physical properties or economic advantages over competing materials in many nonfood uses. Wheat gluten finds difficulty competing on an economic basis; furthermore, its chemical and physical properties are not so suitable as some of the other proteins for existing markets. Let us examine some of the reasons why gluten is unsuitable. I shall outline some of the current research areas potentially promising.

Wheat gluten, the water-insoluble proteins of wheat flour, can readily be isolated by kneading flour dough and washing away the starch with a dilute salt solution (1). Although gluten is insoluble in water at neutral pH, it is readily soluble in acidic or basic aqueous solutions of low ionic strength.

Physical Properties

Gluten, making up 80 to 85 percent of the proteins of wheat, can be fractionated into two classes of proteins of about equal quantities by differential solubility in 70 percent ethanol (fig. 1). Gliadin is the fraction that is soluble in 70-percent ethanol and glutenin, the insoluble fraction. The hydrated gliadin is a syrupy material, whereas the hydrated glutenin is a rubbery mass. Together in the gluten, these proteins give the characteristic cohesive and elastic properties that make gluten unique.

All proteins are polymers composed of amino acids. These amino acids give characteristic chemical and physical properties to the various protein polymers. Thus, the properties of any protein must be related to its amino acid composition. This relationship is illustrated in figure 2. Wheat gluten has a unique amino acid composition, which does influence its properties (2). For example, the scarcity of readily ionizable amino acids, such as lysine or glutamic acid, reduces the solubility of the protein at neutral pH. Also contributing to gluten's insolubility is the high concentration of nonpolar amino acid residues like proline and leucine. Extensive intermolecular interactions are believed to arise from the 37-percent glutamine in gluten. Native gluten proteins contain both intermolecular and intramolecular disulfide



The cohesive nature of gluten proteins is not restricted to the hydrated solid state (3). In solution they associate

into larger molecular entities as indicated by viscosity and molecular weight determinations. Figure 3 illustrates the hy-

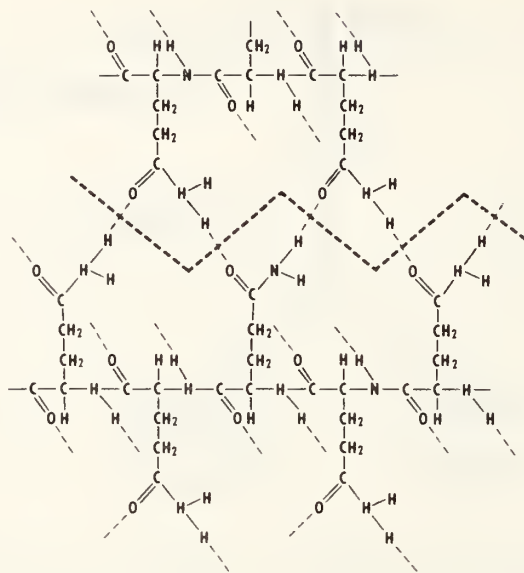


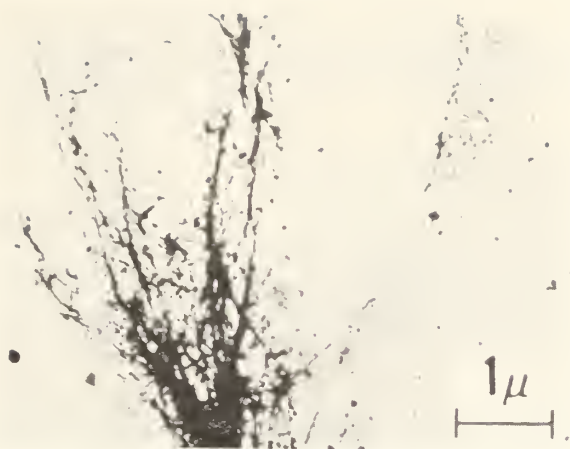
Figure 3.--A proposed structure for crystalline polyglutamine showing hydrogen bonding.

drogen bond interactions between segments of protein containing essentially a polyglutamine structure (4).

Hydrogen bonding exerts a strong influence in the functional behavior of the protein. How proteins from whole wheat flour behave when spread on water is revealed under the electron microscope. Justin (HRS) wheat flour particles were spread on a water surface (fig. 4) and stained with uranyl nitrate, a protein stain (5). The proteins form aggregates and filaments, which appear on this electron micrograph as thin strands forming a network.

All this background must be considered in seeking non-food uses of gluten. The major industrial markets for proteins are as fiber, film, or adhesive compositions. Gluten does not lend itself readily to fiber formation, but films can be prepared from whole gluten (fig. 5). This film was cast from 20 percent solution of gluten and 60 percent ethanol, 20 percent lactic acid and 20 percent water. After the film was cast and dried, the retained lactic acid served as a plasticizer to prevent the film from becoming brittle. Brittleness is believed to result from extensive intermolecular associations.

Tensile strength, percent elongation, and some characteristics of films of several gluten preparations are given in table 1. Films from the laboratory-prepared gluten proteins



Justin (HRS)

$\text{UO}_2(\text{NO}_3)_2$

Figure 4.--Electron micrograph of wheat flour particles spread on water surface.



Figure 5.--A film prepared from whole gluten.

were transparent, whereas those from commercial glutes were translucent and slightly granular. Glutenin formed a stronger film than whole gluten or gliadin presumably because of the extended molecules of glutenin. The films from commercial gluten were not so strong as those from the laboratory-prepared gluten. All the films, those from laboratory-prepared gluten and the commercial material, were extremely brittle, not water resistant, nor did they compare favorably in tensile strength

Table 1.--Tensile strength and percent elongation of
gluten protein films

Film	Film characteristics	Tensile strength	Elongation
		<u>Lb./in.² X 10⁻³</u>	<u>Percent</u>
Whole gluten (lab. prep.)	Clear	1.75	75
Glutenin	--	3.38	63
Gliadin	--	1.42	72
Whole gluten (comm.)	Granular	0.88	400

to some synthetic films. An understanding of what causes these properties may lead to modifications of gluten proteins so they would give better film, fiber, or adhesive compositions.

Gluten's properties can be modified by various chemical treatments. Some of the types of chemical modifications of protein are listed as follows:

1. Cleavage of polypeptide chains
2. Transformation of functional groups
3. Masking of functional groups
4. Crosslinking of polypeptide chains
5. Graft polymerization

I shall now discuss some modifications that have been carried out chemically on gluten and properties of the various products.

Chemical Properties

When gluten proteins are completely hydrolyzed by acid, 20 or more amino acids result. However, if the protein is only partially hydrolyzed by mild acid hydrolysis, polypeptides are obtained. The polypeptides are fragments of the protein. They are smaller and contain more ionizable functional groups than the protein; therefore, they are much more water soluble and can be modified more readily.

Polypeptides derived from gluten proteins to yield products of potential nonfood use were prepared and studied at IIT Research Institute under a contract from the Northern Regional Research Laboratory.^{1/} Preparation and examination of these products for such uses as detergents, chelating agents, adhesives,

^{1/} IIT Research Institute, Chicago, Illinois, Grant No. 12-14-100-7769(71), U.S. Department of Agriculture, administered by the Northern Regional Research Laboratory, Peoria, Illinois.

sizings, coatings, and related materials were the objectives of the contract.

Wheat gluten was converted to polypeptides by mild hydrochloric acid hydrolysis (fig. 6). The hydrolysate was fraction-

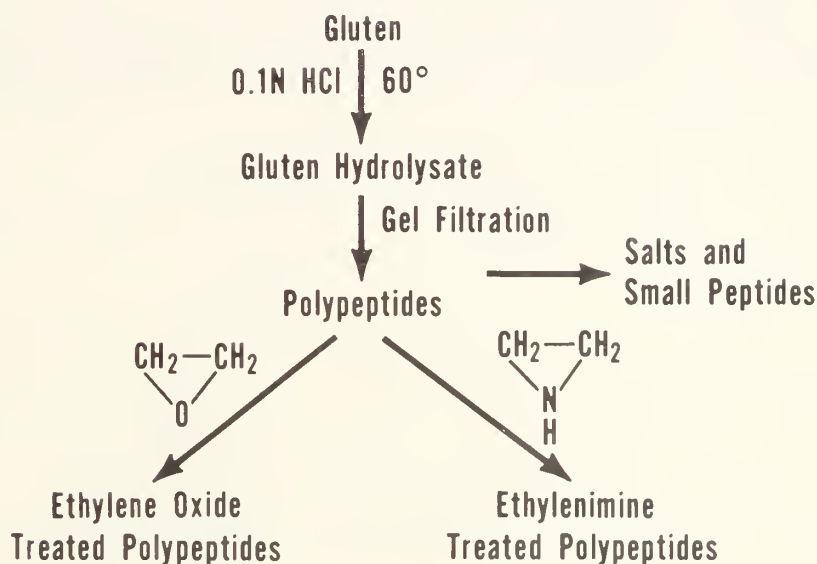


Figure 6.--Polypeptide preparation and treatment with ethylene oxide or ethylenimine.

ated by gel-filtration chromatography, which separated ammonia and small peptides from the major quantity of larger polypeptides. The polypeptides were soluble in dilute acetic acid or in water after neutralization. The molecular weight and size distribution of these products were determined by ultracentrifugation and viscosity measurements (6).

The polypeptides were chemically modified by high-pressure reaction of the polypeptides with ethylene oxide and ethylenimine to give derivatives having promising properties. Table 2 gives

Table 2.--Composition of gluten polypeptides and derivatives

Compound	N	Polypeptide
	Percent	Percent
Gluten polypeptides	10.9	100
Ethylene oxide polypeptides	1.7	16
Ethylenimine polypeptides	21.2	53

the composition of the modified polypeptides. The product from the reaction with ethylene oxide contains about six parts of ethylene oxide to each part of gluten polypeptide. The ethylenimine, seemingly less than normally reactive under these conditions, is present in the product in about equal quantities to the polypeptides.

The epoxidized polypeptides imparted plastic and pressure sensitive adhesive properties to acrylic resins. The pressure sensitivity of acrylic-based adhesives containing epoxidized gluten polypeptides could be varied by changing the concentration of the modified polypeptides. The adhesive bond strength for these formulations was relatively good by comparison to known materials. However, the peel strength of the bond decreased as the quantity of the epoxidized polypeptides increased (7). To obtain optimum bonding, the amount of the polypeptide derivative in the adhesive formulation must be limited to 60 percent, and 33 percent is preferable. The pressure-sensitive properties of these preparations remain essentially unchanged when exposed to air for 8 weeks.

Another area in which gluten polypeptides and the modified polypeptides have been tested is in films. But films from the polypeptides were so brittle that they could not be removed from the casting plate without shattering. The addition of one part of the epoxidized derivative to one part of unmodified polypeptides gave a film with good flexibility. A 1 to 6 or 1 to 10 level gave little or no plasticizing effect (fig. 7). This result is illustrated by the small elongation in the range of 5 to 7 percent.

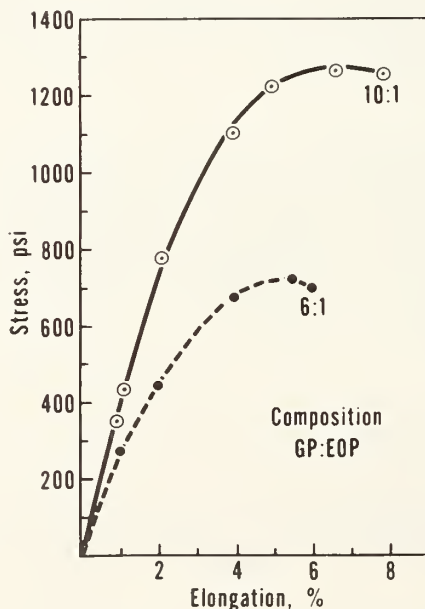


Figure 7.--Plasticizing property of epoxidized polypeptides in films.

Films from whole wheat gluten, without plasticizer, are very brittle. A 1 to 1 mixture with epoxidized polypeptides gave good films, although they were not transparent. The epoxidized derivative is an effective plasticizer for polyvinyl alcohol films at a 1 to 1 level. This derivative has also been shown to be effective as a plasticizer in normally brittle epoxy resins.

The ethylenimine derivative is also an effective plasticizing agent. Films from wheat polypeptides when plasticized with the ethylenimine-treated polypeptides were quite strong. The tensile strength of the films decreased as the content of the ethylenimine-treated derivative increased (fig. 8). But

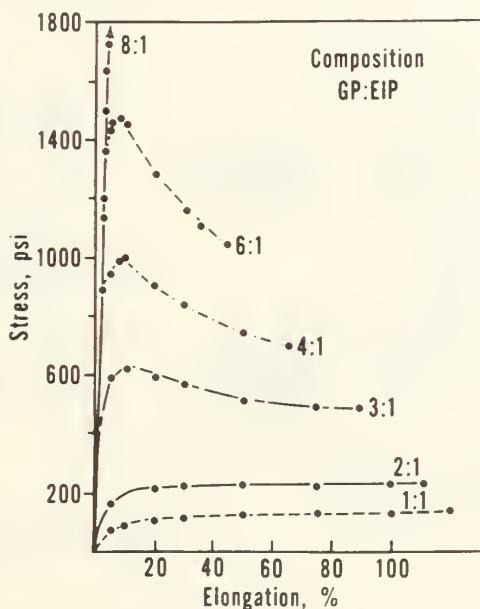


Figure 8.--Plasticizing property of ethylenimine polypeptides in films.

the increased content of the ethylenimine derivative was accompanied by better flexibility. A film containing six parts of polypeptides to each part of ethylenimine derivative had a yield strength of 1,500 p.s.i. and an elongation yield of 15 percent. Although these films have a tensile strength about 1/10 that of cellophane, they are in the range of some of the synthetic films, such as polyvinyl chloride. Comparable films were prepared with the ethylenimine derivative as a plasticizer for polyvinyl butyrol and for polyvinyl alcohol.

Films from the polypeptides and the ethylenimine derivative (6 to 1) were very resistant to oil penetration. No penetration of the polypeptide films by oil was observed, where-

as oil did penetrate comparable films from polyethylene. Some of these films have been evaluated for special purpose packaging. Films of gluten polypeptides plasticized with ethyl-enimine-treated polypeptides made satisfactory packaging materials for measured amounts of laundry detergent. The bags dissolved in water and released the detergent in 30 seconds. Similar packages were made with the epoxidized polypeptides as plasticizer; however, the marked tackiness of the films made them unsuitable.

The future potential of gluten in nonfood uses must be based on finding suitable modifications of the protein. Beside its acid modification, direct chemical reactions can be performed on the gluten. A most logical site for a specific reaction would be at the primary amide group of glutamine (fig. 9).

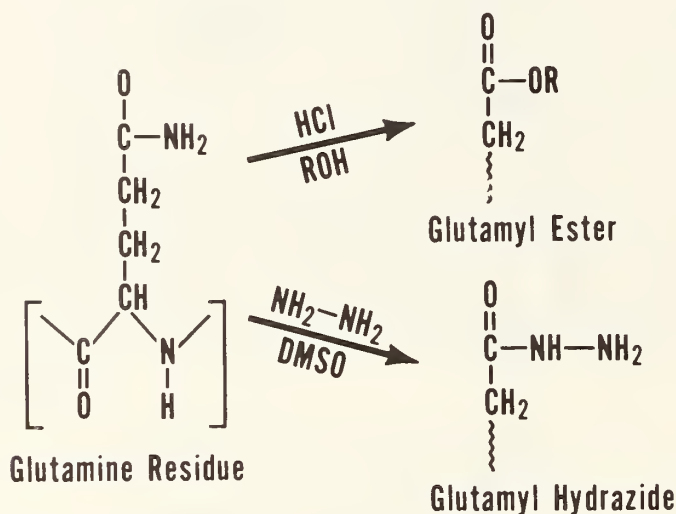


Figure 9.--Types of chemical reactions that can be performed on gluten.

This amino acid represents more than one-third of the protein. Therefore, modification of this amino acid should greatly alter the properties of the protein.

The amide groups can be converted to esters by treatment with hydrochloric acid and alcohol.^{2/} Products can be produced with a variety of properties by changing the alcohol from methanol to benzyl. The product from benzyl alcohol forms water-insoluble films comparable to those from polybenzyl glutamate. However, the strength of gluten films with some amide groups converted to methyl esters was not appreciably increased. Ester-

^{2/} Aranyi, C. and Hawrylewicz, E. J., U.S. Patent (in preparation).

ified gluten proteins are more soluble in organic solvents and less soluble in acidic and urea-containing solvents.

Modification of the amide groups with hydrazine in dimethylsulfoxide has also been carried out (8). Up to 40 percent of the amide groups of gluten can be converted to hydrazides. These hydrazide-modified glutes are more soluble in acidic solvents owing to the increased basicity of the hydrazide groups as compared with the amide.

Another approach to the modification of gluten has been grafting synthetic chains to the protein (9). This grafting was done in an attempt to overcome the hydrophilic character of the protein and to impart stability (fig. 10). The functional

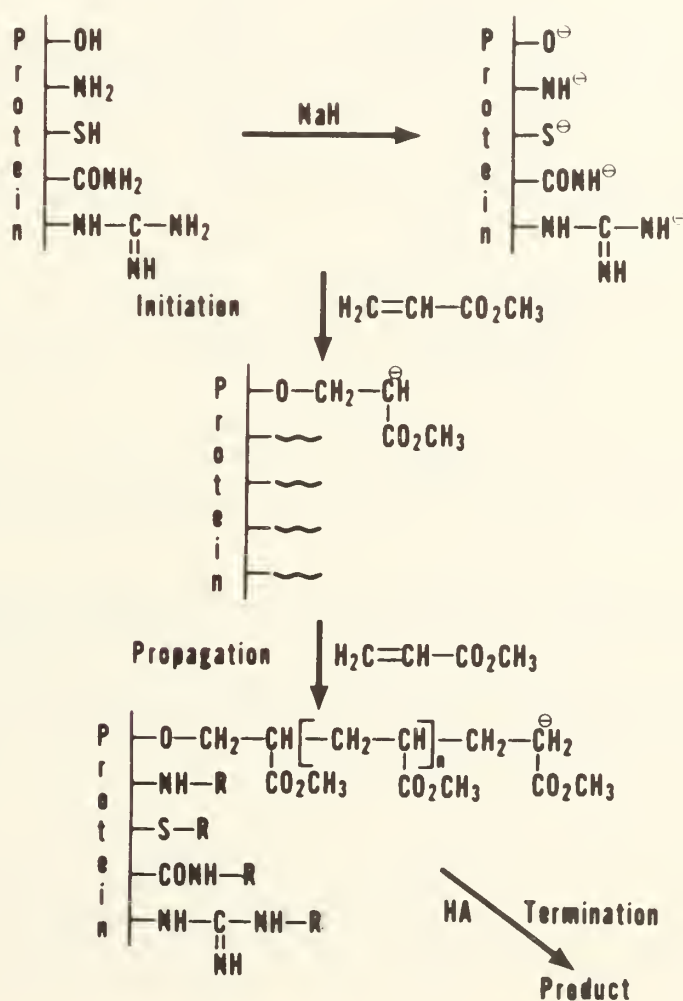


Figure 10.--Functional groups of gluten that will react with sodium hydride in dimethylsulfoxide to produce a protein polyanion.

groups--hydroxyl, amino, sulfhydryl, amide, and imidazole--react with sodium hydride in dimethylsulfoxide to produce a protein polyanion. Addition of a vinyl compound, such as methyl acrylate, initiates polymerization. The rate of polymerization and the ultimate chain length of the grafts depend on the concentration of vinyl compound and reaction time.

This process of anionic-initiated polymerization led to many short grafts of 4 to 12 monomer units throughout protein chain. Figure 11 gives the various vinyl monomers used in these

$\text{CH}_2=\text{CH}-\text{CN}$	1
$\text{---CO}_2\text{CH}_3$	1.14
$\text{CH}_2=\text{C}-\text{CN}$ CH_3	0.28
$\text{---CO}_2\text{CH}_3$	0.22
CH_3 $\text{CH}=\text{CH}$ CN	1.08
$\text{---CO}_2\text{CH}_3$	0.86
CH_3 $\text{C}=\text{CH}-\text{CN}$ CH_3	0.15

Figure 11.--Vinyl monomers used to give gluten graft polymers.

modifications. Also shown is the effect of structure and functional groups of the vinyl compounds on reactivity. Varying the functional group of the monomer from ester to nitrile had little effect. However, a methyl group substituted onto the double bond does exert an influence as shown by the relative rate of methyl methacrylate.

Many more modifications of gluten are possible, but adequate testing and evaluation of existing products have not been completed. Greater emphasis must be given to testing and evaluating gluten products if suitable nonfood markets are to be developed. Properties must be obtained that would make the protein more suitable for fiber, film, adhesive, or unique specialty markets.

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WATER RESISTANT PLYWOOD ADHESIVE BASED ON WHOLE WHEAT FLOUR

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Wheat starch and other starches have been used in the preparation of adhesives for many years. Starch adhesives have become extremely varied both in method of preparation and application. The principal uses have been for carton sealing, container labeling, corrugated board manufacture, bag seam sealing, envelope gums, and other paper uses. These adhesives have many desirable properties but their chief disadvantage is that they do not produce a waterproof bond.

Attempts have been made to use starch adhesives in the manufacture of plywood, but lack of a waterproof bond has limited their use to interior grades. Even for interior grades, phenolic, urea, or melamine resins must be added to the starch adhesive to increase water resistance. Commercial plywood adhesives for exterior use do contain starch or wheat flour, but in very low concentrations for the sole purpose of acting as extenders or fillers.

Phenolic adhesives produce strong, waterproof bonds for plywood. They have the disadvantages of fairly high cost and glue lines that are dark in color. Therefore, they cannot be used to assemble thin decorative veneers because of bleed through. Even when an interior formulation with its lower resin content and higher concentrations of fillers and extenders is used, the dark color at the bond is still pronounced. Protein glues and urea or melamine formulations are, therefore, almost exclusively substituted for phenolic resins in high quality decorative veneer work.

Adhesive from Whole Wheat

A grant from the Washington Wheat Commission for research on novel uses for wheat led to experiments designed to use wheat flour as the base for a plywood adhesive.^{1/}

When attempts were made to make a lighter colored glue line with a commercial phenolic plywood adhesive, it was necessary to reduce the amount of resin added to the mix because the dark color of the cured phenolic resin causes discoloration. This reduction in phenolic resin weakened the resultant bond and led to an unsatisfactory plywood structure. However, the

^{1/} Adams, M. F., Raff, R. A. V., and Austin, H. F. Adhesives Age: 34-36, September 1969.

addition of wheat flour in sufficient quantity to take advantage of the adhesive quality of the wheat starch restored the strength of the glue bond. The use of a very slightly condensed phenol-formaldehyde resin in combination with wheat flour¹ produced a strong and colorless plywood bond. The strength of the bond thus produced is greater than that obtainable with either the resin or the starch.

Two explanations can be visualized for this unexpected result. One is based on the suggestion of Hewett, Carget, and Church^{2/} that starch probably forms a chemical union with phenol-formaldehyde resins in adhesive compositions which may account, therefore, for the increased strength.

Pre-gelatinization of the starch before curing in the press appears to be necessary since mixes prepared from more highly condensed resins did not cause starch gelatinization and did not result in satisfactory plywood bonds.

Preparation of Adhesive

The adhesive is prepared by mixing suitable quantities of wheat flour, clay, slightly polymerized phenol-formaldehyde resin, and water. The clay acts as a filler for the gaps on the rough surfaces of the plies. Whole wheat flour, ground in our laboratories in a Unifine Mill^{3/} and screened to pass 100 mesh (which removes the bran), was used in most of the experimental work. It was found necessary to remove the bran to produce an acceptable adhesive. Later, a sample of commercial household wheat flour was substituted for the Unifine flour and also gave satisfactory results.

The resin used was Compregnite Impregnating Resin manufactured by The Borden Company. The resin, as used, contains 59 percent resin solids, is water-white, and has a pH of 8 to 9. As the resin ages it discolours to a dark brown.

A typical formulation for the preparation of an adhesive that will produce bonds suitable for exterior plywood is as follows.

^{2/} Hewett, P. S., Carget, R. E., and Church, R. J. Paper Trade J. 124 (Tappi Sec.): 45-50, 1947.

^{3/} Austin, G. T. "The Unifine Mill," Bull. 298 College of Engineering Research Division, Washington State University, Pullman, Washington, 1967.

	Percent by <u>weight</u>
Unifine wheat flour (100 mesh)	16.3
Idaho clay	1.4
Water	62.3
Compregnite resin	20.0

The flour and clay are dry-mixed, then the water is added gradually under slow stirring (vigorous stirring produces foam!). When all the flour is wetted and no lumps remain, the resin is added with stirring. The adhesive is ready for use as it begins to thicken, usually in about one-half hour.

Test specimens were glued from 8-inch by 8-inch pieces of 1/8-inch Douglas fir plies that had been dried to contain less than 2 percent moisture. Three-ply samples were prepared with a glue spread of 65 pounds per thousand square feet of double glue line. This was equivalent to 6.5 grams for each glue line on the 8-inch by 8-inch panels.

After an assembly time of approximately 10 minutes, the panels were pressed in an electrically heated laboratory press for 5 minutes at 310° to 320° F., under a pressure of 200 pounds per square inch. Upon removal from the press, the panels were further cured for 3 hours in an oven at 300°. This post-press curing corresponds to the procedure conventionally used in the plywood mill where the panels from the press are stacked hot and allowed to cool.

Tests for performance as exterior and interior plywood of the resultant three-ply panels were carried out in accordance with the specifications given in U.S. Products Standard PSI-66 for Softwood Plywood. These included Section 4.3 ("Test for Interior Type Plywood"), and Section 4.4.2 ("Vacuum Pressure Test"). The above formulation passed the standard tests.

The American Plywood Association (APA), in its "Adhesive Policy," effective January 1, 1967, also requires that exterior adhesives shall contain not more than 15 percent of amylaceous or proteinaceous material calculated on the weight of the resin solid in the glue mix. The restriction is to insure that the glue will meet mold resistance requirements. Revision of the APA restrictions on amylaceous and proteinaceous material could

occur as a result of the use of new mold inhibitor compounds such as the insoluble copper salts (Cu-8-hydroxyquinolinolate, Cu-pentachlorophenate).

The APA requires that a glue must average 90 percent of the controls in tensile breakage strengths after 20 weeks' exposure in the mold cabinet. The standard wheat flour glue lasted 14 weeks. After the addition of 1.5 percent copper pentachlorophenate mold inhibitor, the wheat adhesive passed the 20-week mold test with flying colors. The addition of copper pentachlorophenate to the glue mix materially reduced the viscosity but at the same time added a light brown tinge to the finished glue line.

The viscosity and color of the standard adhesive mix containing copper pentachlorophenate can be altered by the addition of acid. Addition of sulfuric or oxalic acid to reduce the pH from approximately 7 to not lower than 4, lowers the viscosity from approximately 20,000 to approximately 2,000 centipoise.

The standard adhesive mix contains about 70 percent water. Water is expensive to ship and tests were made to prepare a glue mix containing less water, that could be diluted when used in the plywood mill. Tests were also made to determine the effects of freezing and thawing upon the standard and the paste mixes. The paste was prepared in the usual way except that 50 percent of the water was left out. The paste was frozen and thawed each day for 7 days, then mixed with the required amount of water and tested in the usual way. A sample of the standard mix was also carried through the freeze-thaw cycles. Both the paste and the standard mix following the freeze-thaw experiments gave better than 90-percent wood failure according to the Standard APA tests.

Considerations of Cost

While commercial exterior adhesives contain 24 to 32 percent resin solids and only 2 to 3 percent wheat flour, our exterior plywood adhesive has a flour-to-resin solids ratio of 1.38 to 1. This results in a very definite cost advantage.

Assuming \$0.04 per pound of wheat flour, \$0.02 per pound of clay, and \$0.108 per pound of Compregnite, the cost of our adhesive is \$0.028 per pound. Although this figure does not include the cost of the fungicide, it compares favorably with the price of commercial exterior plywood resins which, by their much higher concentrations of resin cost approximately \$0.045 per pound.

Similar savings can be expected by the use of either corn or potato starch.

Summary

A colorless adhesive has been developed which produces bonds that pass the Standard American Plywood Association Tests for both interior and exterior grades of plywood. The excellent water resistance of the bond is a unique feature of this adhesive. Both viscosity control and mold resistance can be obtained by using copper pentachlorophenate in the standard mix. Viscosity can also be controlled by adjusting the pH with a small amount of acid. The adhesive has an indefinite shelf life, can be compounded and shipped as a paste, and is not affected by freezing and thawing.

Using wheat flour only as a major component and thus utilizing the adhesive properties of the starch in the flour, the high starch-to-resin solids ratio of 1.38 to 1 results in a considerable reduction in cost when compared with conventional, resin-based plywood adhesives.

Acknowledgments

The financial assistance of the Washington Wheat Commission to carry out this study is gratefully acknowledged. The APA tests described in the paper were carried out by Max Huffaker and Walter Long of the Materials Chemistry Section of the College of Engineering Research Division.

HIGH PROTEIN--LYSINE RICH WHEATS

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At the Fifth National Conference on Wheat Utilization held at Fargo, N. Dak. in 1967, we reported on 12 years of cooperative USDA and Nebraska effort to improve protein content in wheat. We also summarized our work efforts of 1 year on a project supported in part by the Agency for International Development, U.S. Department of State, to screen the USDA World Wheat Collection to identify possible genetic sources of higher lysine and protein containing wheats. At that time we reported on screening data from 2,000 samples. The present report will include data on an additional 10,500 common wheat samples. Screening has been completed but the data have not been calculated for the first 1,000 samples in the durum collection. The remaining 2,500 durum samples will be finished in a few months, and our screening effort on the World Wheat Collection will be completed.

Genes for High Protein Wheat

Twelve years ago the variety Atlas 66 was the only known available genetic source for higher protein content in wheat. Since then the variety Aniversario (P.I. 168714, C.I. 12578) was identified as a high protein genetic source. J. Craddock of the U.S. Department of Agriculture sent seed to Nebraska in 1962. It was increased and used in the breeding program in 1963 greenhouse crosses. The Nebraska fertility-restoring experimental line NB 542437, recently identified in our project, is an additional genetic source to improve protein content.

These three sources for high protein have been crossed in greenhouse experiments in combination with each other to determine if additive effects are possible.

Other wheats with high protein contents have been identified in our screening efforts on the World Wheat Collection. The protein frequency distribution for the first 7,000 samples is shown in figure 1. Protein values ranged from 6.9 to 22.0 percent. Selected data for high protein samples are shown in table 1.

Greenhouse crosses have been made between the highest protein materials and the three known genetic sources for high protein. A new genetic source for high protein would be identified if a cross shows an increase in protein content over the parental material.

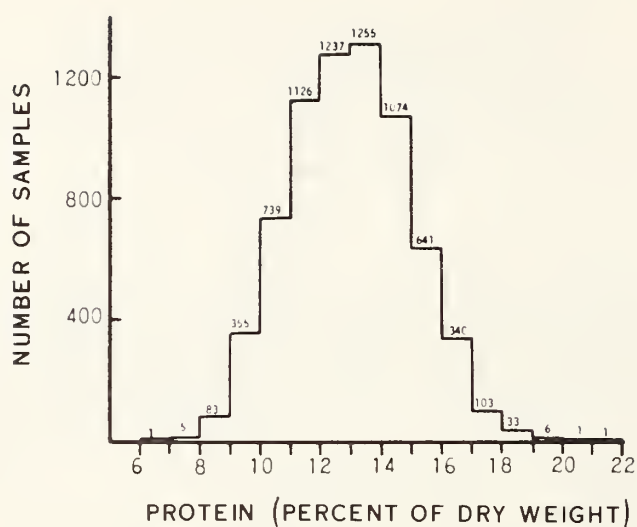


Figure 1.--Frequency distribution for protein content of 7,000 samples from the World Wheat Collection

Table 1.-- Selected high protein samples from World Wheat Collection

Sample No.	1/ P.I. No.	Dry Weight Basis		Lysine/ Protein Percent	Lysine/protein adjusted 2/ Percent
		Protein Percent	Lysine Percent		
10382	225252	21.4	0.58	2.74	3.17
9855	202800	20.9	0.62	3.00	3.40
9883	204008	20.7	0.61	2.98	3.37
10378	225248	20.7	0.60	2.90	3.29
10375	225244	19.7	0.57	2.93	3.26
9678	192812	19.5	0.60	3.08	3.41
9643	192750	19.4	0.58	2.99	3.31
9865	203985	18.9	0.55	2.93	3.23
9637	192738	18.6	0.57	3.09	3.37
9741	196903	18.4	0.56	3.09	3.36
7739	181329	6.9	0.29	4.26	3.89

1/ P.I. - Plant Introduction number.

2/ Values adjusted to 13.5 percent protein.

Strong influence of environment on the level of grain protein does not permit fixing protein content at a specific level. Except under conditions of excessively high soil nitrogen availability, high yields are usually associated with depressed protein content in the grain.

Genes that increase protein content must function in an array of environments and soil fertility levels. Data from wheat performance trials in Nebraska have been reported, which provided evidence of the effectiveness of genes from Atlas 66 to increase protein content in productive varieties. Also, we demonstrated in 1968 that Atlas 66 x Comanche Selection 65307 (a hard red winter wheat selection) maintained its protein superiority over the Nebraska variety, Lancer, in a range of soil fertility levels (fig. 2). In 1969, we extended the level of soil nitrogen and

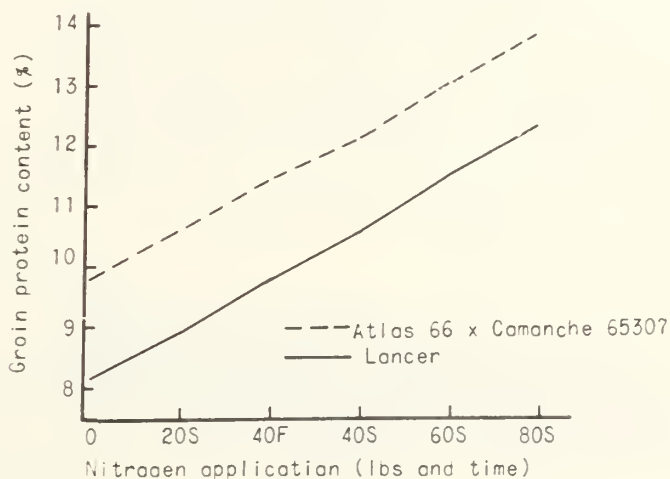


Figure 2.--Response of protein content to increasing nitrogen applications for two varieties of wheat. S=spring; F=fall.

again found superiority at all nitrogen levels. Averages for three growing locations in 1969 are listed in figure 3.

We have several higher protein hard red winter wheats, derived from Atlas 66, in advanced quality testing. The decision to release a line as a new wheat variety may be made soon.

The recent establishment of an International Winter Wheat Performance Nursery in which high protein wheats are being evaluated will provide additional information on the stability and effectiveness of all known high protein genes.

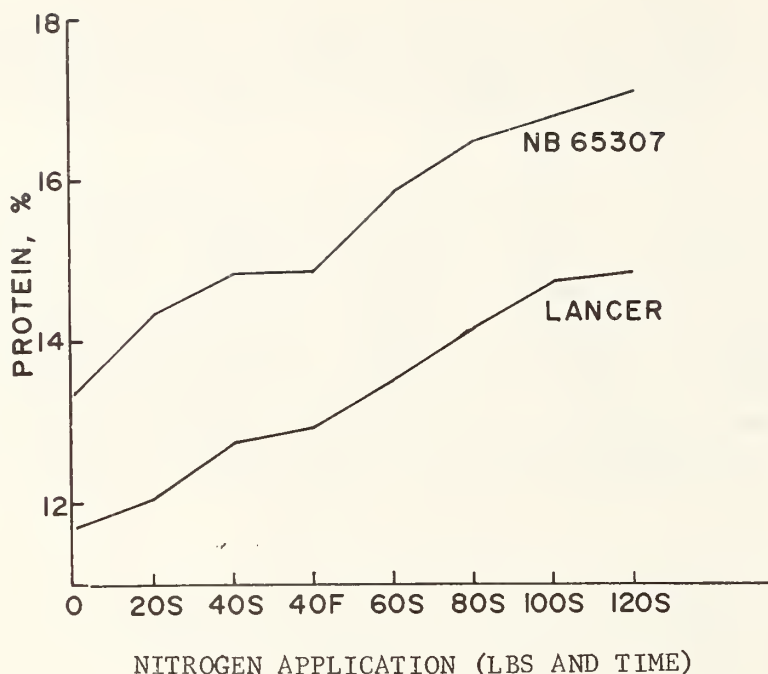


Figure 3.--Averages of results at three locations, showing responses of protein content to nitrogen applications. S=spring; F=fall.

The Search for High Lysine in Wheat

A gene in wheat with major effect on lysine, such as that of opaque-2 in maize, has not been identified. We have analyzed more than 12,500 wheats from the World Collection to date. Lysine values for the first 7,000 samples ranged from 1.7 to 4.15 percent of the protein (fig. 4). The data for the remaining 5,500 also fell within these same general limits.

Wide variations in protein were encountered. The degree to which the measured differences in lysine are genetic has not been established. Lysine data from greenhouse crosses made in the spring of 1969 with high lysine identified materials from the World Collection show some promise. The strong influence of environment on protein level is already well established. Our data suggest that there is also a strong environmental influence on the amino acid composition of the protein.

Lysine level in wheat tends to be negatively correlated with protein. We have recorded highest lysine values for wheats with lowest protein content. The negative regression of lysine (percent of protein) on protein among 7,000 wheats from the World Collection is shown in figure 5. The shaded area indicates the

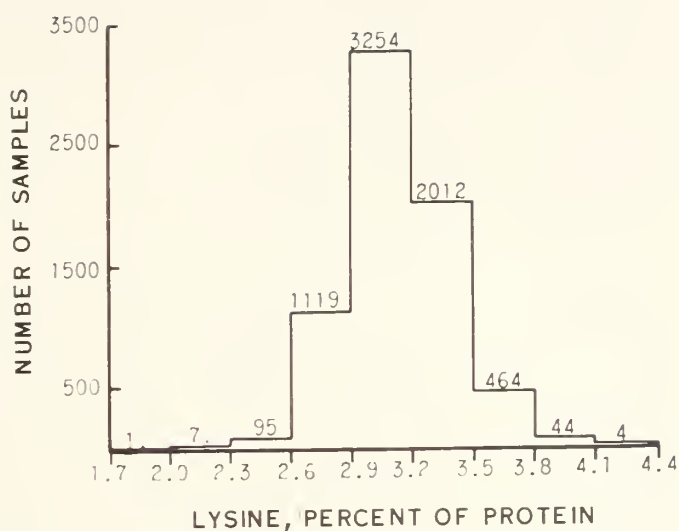


Figure 4.--Frequency distribution for lysine content (as percent of protein) of 7,000 samples from the World Wheat Collection

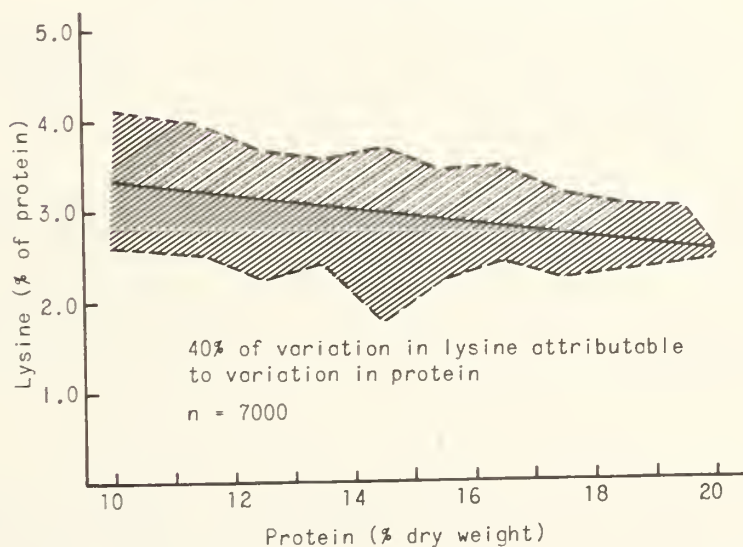


Figure 5.--Relationship of lysine content (as percent of protein) to protein content of 7,000 wheats

range of dispersal of actual values about the regression line. Note that 40 percent of the variation in lysine could be attributed to variation in protein. We now utilize the regression coefficient to adjust lysine values to a common protein level. This provides a means of making lysine comparisons among wheat differing

in protein content. The lysine frequency distribution of 7,000 wheats after adjustment of lysine values to 13.5 percent protein is shown in figure 6. The number of wheats with adjusted lysine values higher than 3.5 percent is only 125 compared with 512 wheats with unadjusted values above 3.5 percent.

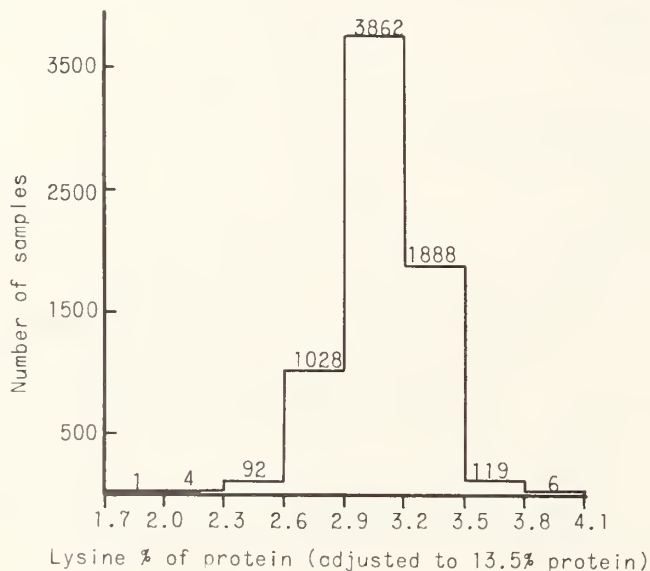


Figure 6.--Frequency distribution for lysine content (as percent of protein) calculated to a 13.5-percent protein basis of 7,000 wheats from the World Wheat Collection

Protein and lysine values of selected high lysine wheats among the first 7,000 analyzed appear in table 2. The wheats are from seven different countries and possess both spring and winter habits of growth. The protein levels of the wheats are low compared to the mean protein level of the 7,000 wheats analyzed. Therefore, adjustment of lysine values to 13.5 percent protein reduced the highest value from 4.15 to 3.91 percent.

Pedigrees of some of the high lysine varieties can be identified. They are shown for eight varieties in table 3. Some possibly significant relationships emerge. C.I. 13252 has the pedigree Norin x Brevor, Sel. 14. C.I. 13447 and C.I. 13449 are derivatives of Norin 10 x Brevor, Sel. 14. Further examination of pedigrees reveals that the old Australian varieties Florence, Federation, and Hard Federation appear frequently. Marquis and Crimean also are in evidence. We believe that some of these wheats may be contributing genes for lysine.

Table 2.--Protein and lysine content of selected high lysine wheats from the World Collection

C.I. or P.I. ^{1/} No.	Origin	Growth habit	Protein content	Lysine (percent of protein)	
				Unadj.	Adj. ^{2/}
			Percent	Percent	Percent
13449	U.S.A.	Winter	9.2	4.15	3.91
142509	Iran	"	9.2	4.15	3.91
11721	Canada	Spring	10.2	4.08	3.89
11696	U.S.A.	Winter	11.1	3.97	3.83
117421	Turkey	Spring	7.7	4.12	3.80
135073	Afghanistan	"	7.5	4.09	3.76
121815	India	"	8.1	4.04	3.74
112344	England	Winter	9.1	3.95	3.70
13447	U.S.A.	"	10.3	3.87	3.69
109595	Turkey	Spring	9.1	3.91	3.66
.					
$\bar{x}$ (7,000 wheats)		--	12.9	3.12	3.08
.					
5483	USSR	Spring	14.3	1.77	1.81

^{1/} C.I. - Cereal Investigation No.
P.I. - Plant Introduction No.

^{2/} Values adjusted to 13.5 percent protein.

Comparison of Essential Amino Acids from Selected High Protein and High Lysine Wheats Identified During Screening of the USDA World Wheat Collection

Seed increases for the USDA World Wheat Collection are made sequentially at Mesa, Ariz. Many samples, therefore, are not adapted to the one environment. Also, the samples represent a number of different growing seasons. However, we were interested in analyzing high protein and high lysine samples for their amino acid content.

A comparison of the essential amino acids, for selected wheats, is shown in table 4. The high lysine selections were superior in lysine, methionine, valine, and tryptophan.

We have noted a correlation of lysine and tryptophan for these 24 high lysine samples and are continuing to evaluate this association.

Table 3.--Parental relationships among high lysine wheats

C.I. No.	Lysine content	Pedigree ^{1/}
13449	3.91	Norin 10-Brevor, Sel. 14 x Sister to Brevor
11721	3.89	Pentad x Marquis
11696	3.83	Ridit x Utah Kanred
13447	3.61	Norin 10-Brevor, Sel. 14 x Rio-Rex
11723	3.58	Hope x Ridit
13058	3.51	Marfed x Merit-28
12052	3.50	Comet-1110 x H44-Ceres
13253	3.50	Norin 10 x Brevor, Sel. 14

<u>1/</u> <u>Brevor</u> (Florence, Federation)	<u>Ridit</u> (Turkey, Florence)
<u>Kanred</u> (Crimean)	<u>Rio-Rex</u> (Crimean, Hard Federation)
<u>Hope</u> (Marquis, Hard Federation)	<u>H44 and Hope</u> (Marquis)

Table 4.--Comparison of essential amino acids from selected high protein and high lysine wheats

Amino acid	High protein ^{1/} percent	High lysine ^{2/} Percent
Lys	2.89	3.58
Ile	3.68	3.69
Leu	7.12	7.37
Met	1.49	1.67
Phe	5.20	4.88
Thr	2.97	3.37
Val	4.48	4.78
Trp	1.12	1.53

1/ Average 24 samples.

2/ Average 55 samples.

Non-endosperm proteins are richest in lysine (over 4 percent) whereas endosperm proteins are relatively poor in lysine (approximately 2 percent). Differences in kernel morphology could alter the ratio of endosperm to non-endosperm proteins, thereby affecting the overall lysine content of the kernel. Kernel size of four varieties as established by passing the grain over appropriately sized sieves had no effect on either protein content or lysine level (table 5). Kernel configuration determined by kernel plumpness and crease characteristics strongly affected the protein

content of kernels but had little effect on lysine expressed as percent of protein (table 6).

Table 5.--Average effect of kernel size on the protein and lysine content of the grain of four wheat varieties

Kernel size	On sieve	Protein <u>Percent</u>	Lysine/ dry wt. <u>Percent</u>	Lysine/ protein <u>Percent</u>
Large	# 8	12.7	0.38	3.1
Medium	# 7	12.2	.38	3.2
Small	# 6	12.5	.38	3.1

Table 6.--Average effect of kernel size and configuration on the protein and lysine content of the grain of four wheat varieties

Size	Kernel Configuration	Crease	Protein <u>Percent</u>	Lysine/ dry wt. <u>Percent</u>	Lysine/protein <u>Percent</u>
Large	Plump	Closed	12.0	0.37	3.15
"	"	Open	12.6	.39	3.13
"	Wrinkled	--	14.3	.43	3.02
Small	Plump	Closed	11.8	.38	3.31
"	"	Open	12.9	.40	3.24
"	Wrinkled	--	15.4	.37	3.04

Contribution of increased protein content to the nutritional value of cereals must be recognized. When wheat with 17.2 percent protein is compared with high lysine wheat at 8.3 percent protein, 100 grams of the high protein grain provide more of all essential amino acids than does an equivalent quantity of the high lysine wheat (table 7).

Food and Agriculture Organization (FAO) standards for amino acids and nitrogen intake of 6.65 grams per day for an adult human weighing 70 kilograms were utilized to compute the weight of grain needed to provide minimal amounts of each essential amino acid. Grain weights for different types of wheat are contained in table 8. Only 355 grams of wheat with 17.2 percent protein would be required to provide man with his minimal amino acid requirements compared to 548 grams ordinary wheat with 11.1 percent protein and 649 grams for high lysine wheat at 8.3 percent protein.

The problem to maximize the protein nutrition of wheat is obvious. One must identify a genetic source for lysine and com-

bine it with the best genetic source of high protein. In addition, production practices must be followed to insure adequate protein levels.

Table 7.--Comparative essential amino acid composition of normal, high lysine and high protein wheat

Amino acid	Normal 11.1 percent protein		High lysine 8.3 percent protein		High protein 17.2 percent protein	
	Percent of protein	Grams per 100 g. grain	Percent of protein	Grams per 100 g. grain	Percent of protein	Grams per 100 g. grain
Lysine	3.0	0.33	3.6	0.29	2.9	0.49
Isoleucine	3.5	.39	3.7	.31	3.7	.64
Leucine	7.0	.78	7.3	.61	7.1	1.22
Methionine	1.5	.17	1.7	.14	1.6	.28
Phenyl- alanine	4.9	.54	4.9	.41	5.2	.89
Threonine	3.0	.33	3.4	.28	3.0	.51
Valine	4.3	.48	4.7	.39	4.5	.77
Tryptophan	1.3	.14	1.5	.12	1.1	.19

Table 8.--Weight of wheat^{1/} needed to provide an adult human weighing 70 kg. with his minimal essential amino acid requirement

Amino acid	Normal 11.1 percent protein	High protein 17.2 percent protein	High lysine 8.3 percent protein
	Gram	Gram	Gram
Lysine	524	<u>355</u>	600
Isoleucine	448	271	561
Leucine	259	165	330
Methionine	<u>548</u>	325	<u>649</u>
Phenylalanine	216	131	285
Threonine	351	229	418
Valine	365	226	446
Tryptophan	404	306	485

^{1/} Dry-weight basis.

International Winter Wheat Performance Nursery

High protein selections from the screening project have been crossed with known genetic sources for high protein to identify still other genetic factors for increasing protein content in wheat. In addition, wheats with highest lysine levels have been crossed with known high protein materials.

An International Winter Wheat Performance Nursery was established in 1968 in cooperation with Agricultural Research Service of the U.S. Department of Agriculture; the Centro Internacional de Mejoramiento de Maiz y Trijo (CIMMYT-Mexico); and the Food and Agriculture Organization of the United Nations. It was grown at 23 sites in 16 countries in 1969 (fig. 7). Seed



Figure 7.--Locations of International Winter
Wheat Performance Nurseries
(23 sites; 16 countries)

harvested at each site is returned to Nebraska for protein and lysine analyses. Certain selected samples will be analyzed for total amino acid constituents.

This international nursery will be valuable to determine the range of environmental effects and to identify genetic sources that are most stable in diverse environments.

HIGH YIELDING WHEATS, THE MILLING AND BAKING OUTLOOK

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During the past decade and a half, considerable research has been conducted on means of increasing the yield potential of new wheat varieties. The success of this program recently has been referred to as part of the "green revolution" which has caused a number of beneficial factors to occur throughout the world. Indeed, in some areas of the world, such as India, Pakistan and Turkey, the "green revolution" may alleviate hunger and solve many of the food and nutrition problems that have been plaguing these areas where bread is usually consumed without leavening.

Because of the success in increasing wheat yields, many varieties also have been used in North America. Here historically, wheat has been used in the milling and baking industry where yeast-leavened products are the ultimate consumer product of the wheat industry. Because quality is measured in terms of end-product performance, frequently, the layman must be confused by outstanding statements of merit relative to the "green revolution" in some parts of the world, in others, by statements relative to concern about maintenance of quality.

The quality characteristics of semidwarf wheats have been studied for a number of years. Norman Borlaug of the Rockefeller Foundation has indicated that only in the last few years have acceptable quality characteristics been observed in selections of the semidwarfs. In general, the quality characteristics that have been of concern to the workers in the program in Mexico include a tendency toward lack of extensibility and toughness of the dough and small loaf volumes.

Indeed, in tests conducted on semidwarf spring wheats which have arisen from a number of the experiment stations in the upper Midwest, these types of problems also have been observed. In reviewing the quality characteristics of semidwarf wheats, it would appear that we are currently at the stage of development in this research program where quality characteristics may be categorized as highly variable. Because of this degree of variability, there is considerable hope that semidwarf springs having reasonably good quality will be produced.

We will review some of the quality characteristics related to the milling, dough handling, and baking processing characteristics of semidwarf wheats.

Gaines was the first semidwarf wheat to be released (1961) in the United States. Since that time, considerable emphasis has been placed on the development of short wheat varieties. The original cross of Norin 10, a Japanese semidwarf wheat, and Brevor, was made in 1949 in the greenhouse at Pullman, Wash. Eventually, this cross led through other crosses and selections to Gaines wheat, a soft white winter wheat.

Since that time, widespread use has been made in breeding programs of the Norin 10 wheat which has the semidwarfism in its germ plasm. Little information is available on the inheritance of semidwarfism derived from the Japanese germ plasm. However, in recent years, breeders of virtually all classes of wheat have incorporated into their breeding programs the semidwarf characteristics. Using this line of reasoning, Dr. Borlaug initiated a program in Mexico in which he endeavored to concurrently develop higher yielding, broader adapted varieties with improved agronomic type, improved disease resistance and improved milling and baking quality. For those of you who are not familiar with the CIMMYT program in Mexico, perhaps it would be appropriate to indicate that, to date, some 16 semidwarf wheat varieties have been released. These are listed below. Also some other names of sister selections of some of these same crosses have appeared. The primary objective of this program has been to seek means of producing wheat varieties having increased yield. Consequently, the milling and baking quality characteristics present a wide quality spectrum.

Varieties developed and released by CIMMYT^{1/}:

Pitic 62	Lerma Rojo 64	Noroeste 66	Azteca 67
Penjamo 62	Mayo 64	Siete Cerros 66	Bajio 67
Sonora 63	Tobari 66	Jaral 66	Nortena 67
Sonora 64	Inia 66	Ciano 67	Oviachic 65 (durum)

Other names or sister selections of some of the same cross:

PV-18, also known as V-18 (red grain)
S-227, also known as Kalyan 227 (white grain)
S-309, Indus 66, Super X, Mexipak 65

^{1/} CENTRO INTERNACIONAL DE MEJORAMIENTO DE MAIZ Y TRIGO.

With the rapid adoption of the Mexican semidwarf varieties by farmers in the Mexican States of Sonora, Baja California, and Sinaloa, Mexico has rapidly risen from a wheat importing country to an exporter of wheat. To date, many of these Mexican semidwarf varieties are being grown commercially in Pakistan, India, Turkey and other mideastern countries. To the extent that they are materially improving the wheat production capacity of these nations, it is wise to keep in mind that much of the Mexican program was directed toward the creation of new wheat varieties which could grow under irrigation and where heavy rates of fertilizer could be applied. Under these conditions, the high-yielding dwarf varieties will greatly out perform the common tall, strong varieties. Dr. Borlaug feels that any farmer who grows wheat under irrigation and who has once grown dwarf varieties will never again accept the tall, strong types.

The advent of semidwarf varieties has renewed interest in the height of the wheat plant. The advantage of the semidwarf types, which have a straw that is from 5 to 10 inches shorter than the conventional varieties, is obvious. Less straw need be processed at harvesting. The shorter straws would tend to be more resistant to lodging and the opportunity for direct combining is materially enhanced.

The wheat plant height varies from very short or full dwarf wheat types (ca. 6 inches) to the normal height wheat (ca. 38 inches) in a field. Obviously, with this range in plant heights, which can be related to the genes, the plant breeder now has a powerful tool which materially assists him in creating plants of desirable heights for wide adaptive regions in the world.

Another advantage of the semidwarf varieties is an insensitivity to the length of daylight. Many of our standard varieties are sensitive to day length. For example, in a spring wheat region, planting normally occurs during April and May and harvesting occurs during August and September. When these same seeds are planted in Mexico, where the day length is 3 or 4 hours less than that typical for the northern Great Plains region, plants planted in October or November will not be mature until April. Indeed, in certain instances those plants that are highly sensitive to the length of the day may not reach maturity even in this extended period. Obviously, plants that are insensitive to length of day and that will mature in a wide geographic region of the world open up many opportunities for plant breeding. Indeed, tests involving experiments in the International Spring Wheat Field Nurseries have shown great advantages in yields for the semidwarf wheats over the normal common varieties that have been developed specifically for certain areas. The results of the international spring wheat yield nursery are shown in table 1. One will note that the variety which has

Table 1.--International Spring Wheat Yield Nursery (CIMMYT)

Variety	1966-67 Crop		1965-66 Crop			
	Yield 36 Sta.	Rank ^{1/}	Yield 50 Sta.	Rank ^{1/}	Yield St. Paul, Minn.	Rank ^{1/}
	Bu./acre		Bu./acre		Bu./acre	
Pitic 62	54.9	1	47.6	4	25.0	11
Penjamo 62	50.7	3	49.7	1	26.2	7
Sonora 64	44.1	8	36.6	16	28.0	4
Jaral 66	43.5	9	44.4	7	28.1	3
Chris	37.3	17	36.6	15	19.9	19
Justin	30.8	18	31.1	18	20.5	18
Selkirk	30.6	19	27.4	19	21.8	16

^{1/} Ranks obtained using the same 19 varieties from the 2nd and 3rd International Spring Wheat Yield Nurseries only.

the greatest potential in 36 stations, Pitic 62, produced 25 bushels of wheat more than the variety Selkirk in 1966-67. However, location is a significant factor and simply because a variety performs well on the average does not mean it will perform well at all locations. In the 50 station average in 1965-66, Pitic 62 ranked fourth, but among varieties at St. Paul, Minn. in that same year it ranked eleventh. These data point out that semidwarfs also show environmental effects which influence their yield.

Another advantage of the semidwarfs is their response to heavy fertilization. Because the short straw wheats are less apt to lodge, heavy application of fertilizer, particularly nitrogen, can be applied to these varieties. The fertilizer not only enables the variety to respond with respect to higher yields per acre, but also with increasing protein content of the wheat harvested. Table 2 shows the effect of fertilizer on yield and protein content.

Table 2.--Effect of fertilizer on yield and protein content

Variety	Treatment #N/#P	Yield	Increase over no treatment	Wheat protein ^{1/}	Increase of protein over no treatment
	Per acre	Bu./acre	Bu./acre	Percent	Percent
Chris	0/50	41.8	0.0	13.9	0.0
"	50/50	44.7	2.9	14.3	.4
"	100/50	49.3	7.5	15.8	1.9
"	150/50	52.9	11.1	16.2	2.3
"	200/50	54.6	13.1	16.2	2.3
Semidwarf	0/50	46.8	.0	9.8	.0
"	50/50	60.2	13.4	11.2	1.4
"	100/50	63.8	17.0	12.6	2.8
"	150/50	65.0	18.2	14.2	4.4
"	200/50	63.8	17.0	14.6	4.8

^{1/} 14-percent moisture basis.

The semidwarf type tends to have a lower protein content, but much of this deficiency in protein appears to be able to be overcome by increasing the level of nitrogen fertilizer. Robert E. Heiner of the University of Minnesota, who has conducted this type of work for many years, is quite confident that data such as shown in this table where test weights, yields and protein contents of a number of treatments of fertilizer with a semidwarf and similar treatments of a standard wheat, suggest that the semidwarfs yield well with respect to the conventional wheat, Chris; and they also have satisfactory test weights. Of considerable significance is the fact that all of the semidwarfs are lower in protein content than Chris or Justin. This then means that specific cultivars have the ability to produce more protein per given weight of seed than do others. This does not mean, however, that more total protein per acre is produced by the higher protein lines. In fact, many of the semidwarfs that are low protein wheats produce more protein per acre because of their increased yielding ability. In terms of increasing protein content, much of the protein deficiency in the semidwarfs can be overcome by increasing the level of nitrogen fertilizer. Two years' data suggest that certain of the semidwarf wheats that respond very favorably to nitrogen fertilizer can realize an increased protein content of 3 to 5 percent when grown in plots fertilized with 150 pounds of nitrogen per acre. Further, these data indicate that some semidwarfs make better use of fertilizer than the normal tall varieties like Chris.

While the data I am showing relates primarily to the Mexican and the spring wheat programs in Minnesota and North Dakota, I do not wish to infer that these are the only areas where work on semidwarfs is progressing. However, these are the areas where we can present factual data. We certainly wish to acknowledge that in many States, such as Washington, Texas, Arizona, Idaho, and California, to name but a few, the work on these types of varieties is progressing. Not only are the State, Federal, and foundation breeders working with semidwarfs, but also a number of private seed companies are working with these types of materials. To date, private breeders have released several for commercial production.

Table 3 gives yield data for North Dakota nursery materials in which a conventional variety, Chris, and a semidwarf were grown under comparable conditions at different locations in the State. For the eastern stations in the Red River Valley at Casselton and Fargo, the performance of the semidwarfs was significantly better than the check variety. As one moved farther north and west, the difference became less apparent and, in the western region at Dickinson, where relatively little rainfall occurred during the

Table 3.--Yield data from North Dakota 1967 crop nursery plots

Variety	Casselton	Fargo	Langdon	Dickinson
	<u>Bu./acre</u>	<u>Bu./acre</u>	<u>Bu./acre</u>	<u>Bu./acre</u>
Chris	40.4	35.0	40.7	21.1
Semidwarf	46.3	46.9	39.5	22.0
Difference in yield between Chris and Semidwarf	+5.9	+11.9	-1.2	+0.9

normal dryland farming period, there was little difference between the semidwarfs and the conventional variety. While these data indicate the tendencies in the 1967 crop, we have noted the same type of tendencies in the 1968 and 1969 crops.

Milling

Millers, bakers and cereal chemists have had considerable apprehension about the quality of the semidwarf wheats. This apprehension perhaps has been precipitated by the normally conservative nature of these types of people because it is extremely convenient not to make a change and, indeed, processing characteristic of some of the semidwarfs do represent a change. The California area is excellent for testing these types of wheat since generally, our normal varieties under this environmental influence will exhibit soft milling characteristics and low protein contents. Therefore, when one finds a variety that mills acceptably from this California environment, one has reasonable assurance that the variety will respond favorably in the normal spring wheat area. There is a wide spectrum in type of milling characteristic exhibited by the bran clean-up of these samples.

Table 4 shows a comparison of milling data derived from semidwarf wheats grown at different locations. These data indicate that the percent patent flour extraction will vary widely depending upon where the variety was grown. Location 1 is in California, location 2 in North Dakota. In the California location, about an 11-percent variation appeared in patent flour extraction, whereas in North Dakota, about 8-percent variation appeared in patent flour extraction. The ash of these flours also varies so widely that it is necessary to develop the cumulative ash curve so that one can properly rearrange and select streams that will be used in making patent flours.

Table 4.--Comparison of milling data of semidwarf wheats grown at different locations

Variety	Location	^{1/} Milling characteristics	Patent extraction Percent	Flour mineral content ^{2/} Percent
Normal spring		Normal	66.9	0.377
Semidwarf A	1	Very soft	57.3	.374
"	2	Very soft	62.1	.366
Semidwarf B	1	Normal	67.4	.428
"	2	Normal to soft	69.6	.420
Semidwarf C	1	Normal	68.8	.367
"	2	Normal	70.3	.395

1/ 1 = California; 2 = North Dakota.

2/ 14-percent moisture basis.

Because of the soft milling characteristics in the parentage of a majority of the present semidwarf types of wheats, there has been a tendency to note a soft milling characteristic. Also, because of the apparent extreme difference in genetic makeup, the semidwarfs do not always appear to be compatible with other wheats when blended before milling. Further studies are currently underway in this area to determine the extent and the effect of the influence of mixing nonvitreous and vitreous types of wheats before milling. However, we are optimistic that the wide range of germ plasm available to the breeders will enable them to incorporate new crosses to create milling characteristics which can alleviate these problems associated with blending incompatibility.

Baking

When one considers the potential baking quality of a flour, one recognizes that there are certain quality characteristics that can be determined both objectively and subjectively. Among these are the important factors of quantity and quality of protein, mixing time and tolerance, dough handling properties, and finally, the volume and general characteristics of the baked loaf of bread. Because there are several different types of baking processes widely used in the world, the layman is often disturbed and confused over the lack of specific quality characteristics that define the value of the flour. However, in most modern-day bakeshop practices, time is a major factor of consideration whether the straight dough, sponge dough, or continuous dough process is used. The baker is acutely aware that if the baking process is conducted over an extensive period, additional costs would accrue.

A series of mixograms for various varieties of semidwarf wheats was studied. An extreme range in mixing times and tolerances, ranging from very short to very long, was observed. One required about three times as much mixing time as normally associated with present accepted varieties. This particular variety required over 1 hour of mixing on a rheograph before the peak time was observed. This is considered to be excessive.

The farinograph is one of the physical dough testing devices which is frequently used for flour purchase specifications by the milling and baking industry. It is simply a recording dough mixer which measures the energy to mix the dough as a function of time. The top curve (fig. 1) shows a normal type of farinogram for a hard red spring wheat. Curve 2 (W1-D) is a farinogram from

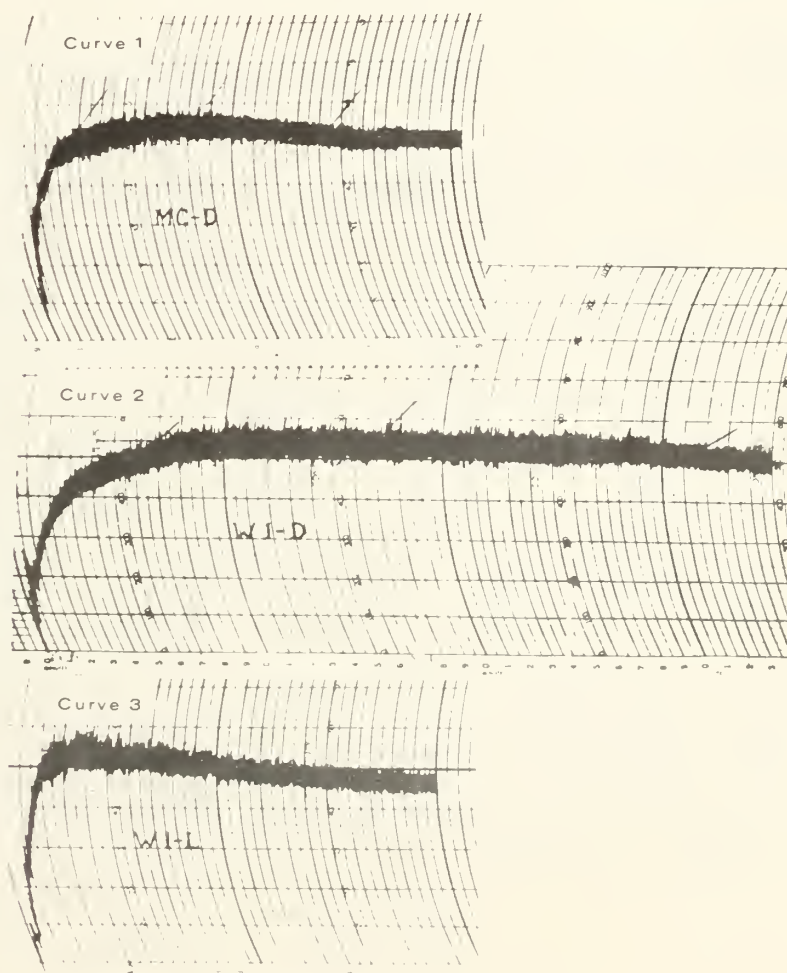


Figure 1.--Farinograph mixing curves for a typical hard red spring wheat flour (curve 1), and for flours from a semidwarf wheat variety grown at two locations differing in climatic conditions (curves 2 and 3).

another semidwarf wheat grown in the same field. This curve shows an undesirably long mixing requirement. It requires more than twice as much time to develop the dough, 7 versus 3 minutes, and to mix it to optimum conditions, 17 versus 8 minutes. In commercial baking practice, this type of farinogram, curve 2, is considered undesirable.

Of additional interest is the fact that the wheat shown in curve 2 which gave the excessively strong curve, may not give a consistent mixing requirement. When it was grown at another location where weather conditions were unusually adverse, the farinogram appeared weaker (curve 3, W1-L) than that for a typical hard red spring wheat flour. Obviously, this type of semidwarf presents potential problems because of inconsistent quality characteristics. In general, we are concerned that semidwarfs may respond very favorably to optimal growing conditions but when the growing conditions are suboptimal, undesirable physical dough properties may result.

Table 5 compares the dough character and baking absorption of five semidwarfs with the normal height variety, Chris.

Table 5.--Comparison of dough character and baking absorption of five semidwarfs with the normal height Chris variety

Variety	Fargo, N. Dak.		St. Paul, Minn.	
	Dough character	Absorption ^{1/}	Dough character	Absorption ^{1/}
		Percent		Percent
Chris	Strong	64.7	Strong to medium	66.0
Semidwarf A	Medium	65.0	Weak	61.3
" B	Medium to weak	65.2	Medium to strong	62.8
" C	Strong	62.3	Medium	61.0
" D	"	65.3	Medium to strong	66.0
" E	Very strong	68.5	Strong	70.9

^{1/} Baking absorption on a 14-percent moisture basis.

A wide range in dough properties from weak to very strong is shown. Some of these varieties are so bucky in nature that on continual handling, they become almost unmanageable. Some of these characteristics of the dough appear to be attributable to the nature of the protein within these varieties. Research on this particular problem is currently underway.

Table 6 shows some of the loaf volume characteristics of semidwarf wheat compared with Chris, a conventional wheat.

Table 6.--Loaf volume comparison of five semidwarfs with the normal height Chris variety

Variety	Loaf volume percentage of Chris		
	Fargo, N. Dak.	St. Paul, Minn.	Average
Chris	100.0	100.0	100.0
Semidwarf A	88.6	74.9	81.8
" B	76.7	90.8	83.8
" C	93.3	87.0	90.2
" D	102.1	91.3	96.7
" E	109.3	103.9	106.6

The range in this quality characteristic is apparent. Semidwarf A displays about 18 percent lower loaf volumes than Chris. Semidwarf D is about the same as Chris, whereas Semidwarf E is about 7 percent better than Chris. Obviously, by employing different treatments and manipulations during the baking process, the volume response of a flour may be varied. However, in the case of the baking process one is not able to use unlimited resources. Invariably, whether or not a flour is used and a new process adapted will largely depend upon economics. In the event that desirable properties can only be imparted at higher cost, doubtless the baker will strive to find other sources of flour for his particular plant. Some of the excessive strength and buckiness of tough gluten characteristics of some of these semidwarfs usually is associated with loaves of bread that have thick-walled and harsh internal characteristics of the crumb. In some cases, this problem can be alleviated by various types of treatments with enzymes and additives. However, it is felt that this type of approach would be impractical from a commercial standpoint for handling flours derived from these wheats.

The challenge for the plant breeding team is to combine most of the desirable quality characteristics in one new wheat variety. Semidwarf wheats have created such an impact that, doubtless, their popularity will spread. As Dr. Borlaug indicated to me in a recent letter: "...that although there has been a lot of publicity given to the development of hybrid wheat varieties, there is still a long way to go research-wise before a hybrid can be produced with satisfactory agronomic, milling, and baking characteristics. Even after this is accomplished, there still will remain the obstacle of cost in producing the hybrid seed. We do not think that hybrid wheats will make any great change in wheat production within the next five years."

If this prognostication is correct, the high yield types of wheats that the wheat industry will deal with in the foreseeable future will be the semidwarf types.

In summary, we are of the opinion that the semidwarf wheats will be very attractive from the standpoint of the farmer, not only in areas where they were primarily intended to be grown under irrigation and with heavy fertilization, but also in dry-land areas where there is sufficient rain to utilize the greater production efficiency of these types of plants. Because of the shorter straw, the semidwarfs will tend to lodge less, will tend to give larger kernels of wheat, and will tend to be harvested by direct combine in those areas where this technique is applicable. However, in areas such as the pothole country of the Great Plains, there is considerable doubt that direct combining will be able to be accomplished.

The semidwarfs will tend to have a lower vitreous kernel characteristic and may appear to have an increased content of "yellow bellies." This characteristic may tend to place some of the semidwarfs in a lower wheat grade. This tendency toward lower vitreousness is associated with a more starchy type of kernel. This property affected the milling process where one frequently finds that the semidwarf wheats tend to mill more like winter wheats or soft wheats than typical spring wheats. Because of the tendency towards softness, the flour yield of semidwarfs may tend to be slightly higher. However, the absolute yield of patent flour is obviously affected by the ash content.

In studies involving baking quality, a wide range in mixing, dough handling properties, loaf volume, and even internal structure of the loaf itself has been observed. This suggests that the potential for obtaining any specific desirable type of quality characteristic can be bred into semidwarf wheats.

Although we do not know all that we need to know about the production and quality characteristics of semidwarf wheats, it is likely that there will be significant production of semidwarf wheats having acceptable quality characteristics. In the next decade, the relative economic position assumed by the competition of conventional, semidwarf and hybrid wheats may, indeed, suggest that a number of changes in our marketing and utilization patterns concerning wheat will develop.

WHEAT PROTEIN CONCENTRATE IN BAKED GOODS

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Attention has been called to the potential value of certain milling fractions for human dietary use by W. B. Bradley in 1962 at the Conference on the Role of Wheat in the World's Food Supply at Albany, Calif., and the following year by F. N. Hepburn at the Second National Conference on Wheat Utilization Research. The high concentration of well-balanced protein, vitamins, and mineral elements in the red dog and shorts fractions prompted the suggestion that these products might be utilized as low-cost dietary supplements, provided the fiber content could be reduced to an acceptable level and that they could be utilized in readily accepted foods.

Investigations by the milling industry resulted in a process of regrinding and sieving shorts to yield Wheat Protein Concentrate (WPC), a product with reduced ash and fiber contents. In cooperation with the United States Department of Agriculture, WPC was utilized in formulations of Blend A and Wheat-Soy-Blend (WSB). There is currently a great interest in both these products for domestic and overseas use. Incorporation of these two blends in bakery products is the subject of the present discussion.

The composition of Blend A is given below.

	<u>Percent</u>
Straight wheat flour	70
Wheat protein concentrate	30

As evident, Blend A is a simple combination of 70 percent straight wheat flour with 30 percent of WPC. It contains 14 to 15 percent protein (N x 6.25), 1.5 percent ash, 2.3 percent fat, and 1.0 percent fiber. WSB is more complex as shown below.

	<u>Percent</u>	<u>Percent</u>
Wheat fractions, total	38.4	73.4
a. Straight grade flour		
b. Wheat protein concentrate	35.0	
OR		
a. Bulgur flour	53.4	
b. Wheat protein concentrate	20.0	
Soy flour, defatted		20.0
Soy oil, refined, stabilized		4.0
Minerals and vitamins		2.6

The wheat fractions account for 73.4 percent of this blend and consist of a mixture of either straight flour (38.4 percent) with wheat protein concentrate (35.0 percent), or of bulgur flour (53.4 percent) with WPC (20.0 percent). In addition to the wheat fractions defatted soy flour, soy oil and minerals are added. Chemical composition of both types of WSB is similar. It contains at 11 - percent moisture basis not less than 20.0 percent protein (N x 6.25), 0.95 percent lysine, 6.0 percent fat, and not more than 2.5 percent crude fiber and 6.6 percent ash.

The blend with bulgur flour was evaluated in experiments reported in this study.

Experiments With Blend A

The Blend A is designed for use in bakery products for production of low-cost items of high nutritional value. We studied the possibilities to use this blend in the manufacturing of breads and rolls.

Serious difficulties were initially experienced with the blend to produce acceptable breads by conventional procedures. Reduced volume was the principal criticism. As a result of a systematic study of the normal technological variables, it was concluded that best results may be obtained with a straight dough procedure if certain modifications in the dough preparation were observed. The formula selected was:

	<u>Percent, flour basis</u>
Blend A	100.0
Yeast	2.5
Yeast food	.5
Salt	2.0
Lard	3.0
Sugar	6.0
Water	66.0 to 68.0

It is a normal bread formula without milk and rather lean in sugar.

To produce best products the following precautions should be taken.

1. Absorptions as determined by the farinograph give values that are too high for actual baking. It is necessary to keep absorption at somewhat low level and to make the dough of slightly stiff consistency.
2. Mixing of the doughs is critical. The blend has a poor mixing tolerance and a critical mixing peak. Best results are obtained when mixing is held just slightly short of full development.
3. Fermentation tolerance is also poor and needs attention. It should be less than of normal duration.
4. There is a definite advantage of proofing the doughs higher than normal doughs. Proofing to 1-1/4-inch height above the top edge of pan is recommended. Fully proofed doughs are quite stable.
5. Baking at 400° F. for 25 minutes is advised. These conditions tend to improve the loaf volume.

Breads made by this procedure are shown in figure 1.



Figure 1.--Bread made from Flour Blend A by the selected formula and straight-dough procedure.

We were unable to devise a satisfactory sponge and dough procedure for Blend A (fig. 2).



Figure 2.--Breads made from Flour Blend A by a sponge-and-dough procedure.

In addition to breads, different types of dinner rolls (fig. 3) can be produced by using the straight dough procedure. The same precautions should be taken as in the production of bread. Shortening and sugar should be increased to 6 percent and 8 percent, respectively.

Whey-Soy-Blend Experiments

This blend was originally designed for preparation of a highly nutritive gruel for infants. Although suggested as an ingredient for baking, we encountered serious difficulties in using it in bread production. One of the problems is the high amount of gelatinized starch since all components of the blend are precooked before blending. This limits the level at which WSB can be used.

We found that acceptable bread can be made when 20 percent of flour is substituted with WSB. Higher levels cause serious deterioration of bread quality. Conditions for best breads with the WSB are: (a) Use of straight dough, (b) absorption 70 percent, (c) mixing to full development, (d) keeping fermentation short or eliminating it entirely, and (e) keeping pH at about 6.0 with calcium carbonate to minimize bitter flavor of WSB-breads.



Figure 3.--Dinner rolls made from Flour Blend A by the straight-dough procedure.

More promising application of WSB is in cookie production. No technological problems are encountered when 50 percent of WSB is used in place of cookie flour. The normal formula is as follows:

	<u>Percent</u>
Pastry flour	50
WSB	50
Sugar (Sucrose)	75
Shortening	38
Salt	1.25
Soda	1
Water	24
Flavors:	
Lemon	3
Chocolate	20 + 30 percent additional water

Very acceptable cookies were prepared with lemon flavor or chocolate cookies with addition of 20 percent dutched cocoa (pH = 7.9). These cookies were also interesting from nutritional point of view since WSB increased the protein level from 5 to 8 to 10 percent, thus transforming a low protein product into an item of a protein content similar to bread. Bitter flavor, which is a

problem in breads, was overcome by the high sugar and pH of the product.

Nutritional benefits of using the wheat blends are given below.

Component	White flour	White flour + 12 percent milk solids	Blend A
	<u>Percent</u>	<u>Percent</u>	<u>Percent</u>
Total Protein	10.0	12.7	14.2
Lysine	.21	.47	.48
Threonine	.29	.44	.44
Tryptophan	.14	.19	.16
Isoleucine	.36	.49	.50
Leucine	1.00	1.47	1.21
Phenylalanine	.47	.64	.64
Valine	.43	.58	.63
Total sulfur amino acids	.47	.57	.50

The amino acid composition of white flour is compared with that of Blend A and flour with 12 percent milk solids. It is obvious that Blend A supplies equivalent amounts of amino acids as flour with 12 percent milk solids. The WSB at a level at which it can be used in breads (20 percent WSB to 80 percent flour) contributes approximately the same amounts of amino acids as Blend A.

In conclusion, I would like to point out that the reported results are by no means final solutions.

I would like to list a number of unresolved problems. They are: (a) Stability of the blends, (b) nature of bitter flavor of WSB, and (c) general acceptance of the products.

WHAT'S AHEAD FOR THE BAKING INDUSTRY? - PART I

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As civilization progressed, baking procedures have evolved from a primitive art to an exact science. The Egyptians and Babylonians knew baking more than a thousand years before the Christian era and even though the process for making bread has undergone many revolutionary changes, the appearance of bread centuries ago was the same as for some types of bread made today. Thus, the baking industry continues to produce bread in many respects similar to what was produced in ancient times, from grain that has changed but little in appearance, and with the basic processing of grain, namely, grinding and sieving still prevailing after many centuries. This situation does not provide an environment in which there is created a spontaneous impulse to advance new thoughts concerning changes that lie ahead. However, even if the assumption is made that baked products will remain generally the same in the foreseeable future, it can be interesting to speculate on the anticipated changes that will occur in the baking processes, ingredient use, quality specifications, use of various additives, improved nutritive values, and product type and marketing system changes. Changes in those operations in the next 10 to 20 years are certain to bring many improvements in taste, flavor, form, and size of baked products.

To obtain opinions on this subject commercial bakers, representatives of baking organizations, cereal chemists, and flour millers in North America, Europe, and Australia were asked the question "What Changes Lie Ahead for the Baking Industry in the Next 10 to 20 Years?" The following is a summary of the answers received:

Comments from the United States

- (a) Greater mechanization including computerized operations.
- (b) More integrating with other industries and marketing complexes.
- (c) More precise control of all ingredients used by the baking industry.
- (d) Freshness retention or the stale bread problem will be solved.
- (e) New synthetic ferments will be developed.
- (f) Flavoring, taste stimulants, and enzyme system additives will result in improved products.
- (g) Greater production diversification of baked goods resulting in the use of more sugar, milk solids, fats, and others and less use of wheat flour.
- (h) Wheat flour will lose its uniqueness for bread pro-

duction and will decline in importance with the use of gluten substitutes.

- (i) New nutritional knowledge will improve the vitamin, amino acid, and mineral content of baked products.
- (j) Many innovations will occur in the baking industry and tradition will no longer be the guide.
- (k) Baking quality technology of wheat will be understood fully and tailor-made baking quality specifications will be imparted in the flour manufacturing process.
- (l) A decrease in number of wholesale bakers because of improved transportation systems, with more emphasis on restaurant business as the trend to eat away from home increases.
- (m) No diminishing of the importance of the baking industry.

Comments from Foreign Countries

- (a) Further spread of different mechanical dough development processes such as the Do-maker, Chorleywood, Tweedy, Cresta, Oaks, Brimer, and Blanchard systems.
- (b) Home baking and small bake shops will be replaced by large commercial bakeries.
- (c) More extensive use of additives such as oxidants, reducing agents, dough conditioners, enzymes, and new chemical products, such as synthetic bread flavor, will be common.
- (d) Common bread consumption will decrease and special types increase.
- (e) Rye bread production will decrease.
- (f) Use of infrared, microwave, and other types of heat energy will be used to control baking operations.
- (g) Improved control of raw materials and production of more uniform and standard product.
- (h) No success with bread production by artificial means.

Discussion

What do these answers to the question of anticipated changes in the baking industry mean in terms of wheat utilization? Optimistically, the baking industry's future seems secure. There were no predictions other than that a healthy, essential, and expanding industry, vitalized continuously by new equipment, methods, and products would continue in the future. There seems to be no apprehension concerning the future of the baking industry; thus, a market for wheat seems, for the immediate future, to be assured. The changes envisioned in the baking industry concern mechanization, new and improved ingredients, changed baking procedures, new products and new concepts of business organization, but no special concern that the baking business will diminish in importance.

Many of the same predictions regarding future changes in the baking industry were repeated in each reply received. Improvement in the nutritive value of baked products was a common prediction and some answers indicated that improved nutritional values would result from wheat improvement. However, it was interesting to observe that apparently, judging by the letters received, the baking industry is not expected to become the manufacturer of baked products used as carriers for various supplemental food substances. This viewpoint could probably be expected, because wheat flour and bread have served as pioneer food products for experiments in vitamin and mineral enrichment. However, it is also well known that many unsuccessful ventures have been made to market bread on a basis of added nutritional merits. Since the beginning of baking, bread made from wheat flour has had about every conceivable food product added to it in one form or another, without notable success. There seems to be no anticipation that this situation will change soon.

Present developments where so-called bread is made without wheat apparently, at the moment, concern the baking industry only slightly. There is, however, the widely held belief that a substitute for wheat gluten will be developed before long. A trend appearing in various ways in the answers received indicated reduced dependence on wheat as the basic ingredient of the baking industry. Apparently consensus is mounting that the uniqueness of wheat for bread production will some day end.

The challenge, then, for those interested in wheat utilization is to continue to work to be able to supply the baking industry processed wheat of precise chemical, physical, and nutritional specifications under economic terms that prevent other ingredients from becoming substitutes for wheat. Research and development in the future can be expected to produce products that will compete with wheat, but research and development also can be expected to improve the baking quality of wheat, and thus, it will be better able to meet future competition.

WHAT'S AHEAD FOR THE BAKING INDUSTRY? - PART II

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The information that Dr. Shellenberger has just presented to you represents, in essence, the views of persons intimately involved in bakery practice and research in several countries. The views vary widely, but those of you familiar with the industry can recognize manifestations of major trends taking place

in the industry. I would like to spend a few minutes, now, to discuss a couple of these trends, what appears to be behind them, and what they will demand of utilization research.

One of Dr. Shellenberger's comments is rather helpful to set the stage. He pointed out that many forms of baked foods of today differ little from rather ancient forms. He further noted that little impetus for change has arisen spontaneously from within the industry. To me this means, among other things, that the basic products, in general, are well-liked, fit social and emotional needs, and are economically suitable over a wide range of circumstances. This means, also, that the rather profound changes that have taken place in the baking industry of this country in recent decades have arisen from demands outside the industry. These changes have largely economic and sociological origins--the rising costs of production, increasing urbanization of populations, centralization of manufacture, and other factors with which we are familiar. Without question, pressures from such factors as these will continue. In fact, they will increase.

Thus, we have pressure for change opposing pressure for keeping products the same. Breads, rolls, and other products appear to be wanted with essentially their present familiar characteristics, but new ways to make and market them are being forced. Significant change in the products and in their methods of production seems inevitable.

With this brief background, I want to explore some of the technological problems involved, by way of illustration, and by way of emphasizing the tremendous amount of research and development required. Successful accomplishment of this research and development is absolutely essential for maintaining the prominent place in our diets and markets that wheat foods have enjoyed for centuries.

For sake of brevity, I want to use only two examples of the specifics of what I have been talking about. The first of these has to do with continuous automatic baking of bread. I will assume that all here are adequately familiar with the continuous-mix type of baking that supplies about 40 percent of the bread in the United States today. In this process, the rather lengthy preparation of doughs up to the time of panning has been drastically shortened. From the standpoint of total efficiency, however, we still have the time-consuming process of individually panning each loaf, letting it rise (proof) for an hour, baking it for 20 minutes or so, then of cooling, slicing, and wrapping it.

About a year ago in connection with our annual budget operation, I was contemplating all of this information, as well as the increasing sophistication and application of cooker-extrusion processing to cereal-based food products. I could see no real in-

compatibility to incorporating certain features of cooker-extrusion to bread baking. A very short while later, I was both pleased and a little chagrined to learn of a recent patent embodying most of what I had been scheming. I would like to review this patented process very briefly for you to illustrate the sort of processing changes that can very well take place in the wholesale baking industry in the next few years.

By no means do I intend to endorse this particular process or to assure that it will become successfully reduced to practice. Many similar developments are possible and seem quite as feasible, if not more so. I use this example merely as a convenient illustration.

The subject process was invented by Peter J. Booras, who holds two recent patents describing the process.^{1/}

Figure 1 shows that the process is well integrated and that the process is not just a rudimentary framework of an idea. Across the top are most of the items now employed in the continuous-mix bread process. The only exception is a carbon dioxide storage vessel and a device to carbonate the water used for doughmaking. Doughmaking itself takes place in the first two pieces of equipment shown on the bottom line. One of these is an incorporator where all dough ingredients are blended before pumping to the developer. The incorporator is the second piece of apparatus along the bottom line. To this point the procedure is very similar to those commonly used in continuous-mix processes.

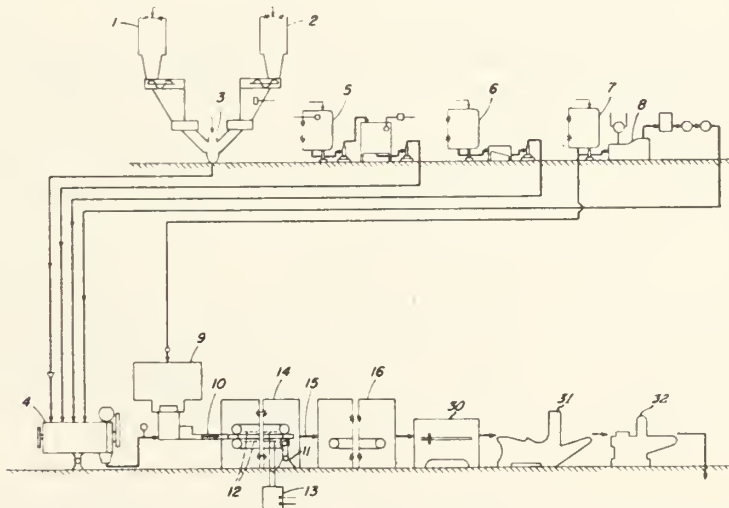


Figure 1.--Breadmaking process and apparatus (after P. J. Bouras).

^{1/} Booras, P. J. Breadmaking process and apparatus. U.S. Patent 3,256,838, June 21, 1961.
Booras, P. J. Breadmaking process. U.S. Patent 3,424,590, January 28, 1969.

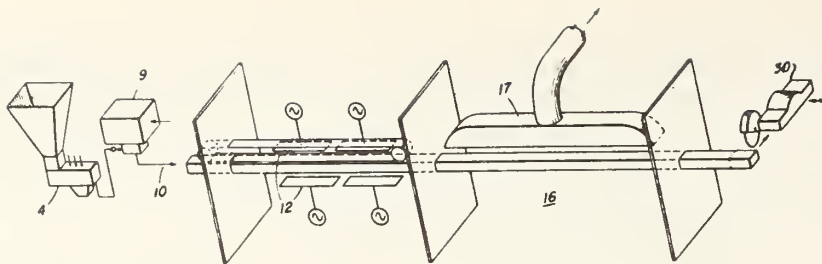


Figure 2.--A schematic drawing of the mixing, baking, and cooling operations (after P. J. Booras).

This schematic drawing (fig. 2) illustrates the mixing, baking, and cooling operations in a crude way. To the left is the mixing section, the center area is baking, and at the right are cooling and the prelude to slicing.

Item number 4 in fig. 2 here represents schematically the incorporator and the various ingredient inputs, including carbonated water. Item 9 represents the dough developer which is also supplied with a line from the carbon dioxide storage tank so that the carbon dioxide content of the dough can be adjusted to desirable levels. This is an essential feature of the process, because the primary leavening is almost exclusively furnished by externally supplied carbon dioxide, rather than by that produced by yeast within the dough.

As the dough is extruded from the developer, it will expand immediately and considerably, the extent depending upon the difference in pressure between that in the developing chamber and that external to the chamber. The entire apparatus from this point on through the cooking step is enclosed so that the pressure on the extruded dough and baking bread can be regulated and controlled.

Instead of cutting the extruded dough into pieces and dropping them into pans, the stream of dough is picked up to be confined and shaped into a continuous bar at the point indicated by the numeral 10 on the drawing. As the dough is extruded from the mixer, it immediately enters a troughlike channel to be carried through the subsequent baking step.

Figure 3 illustrates how four moving belts are arranged to form the channel which shapes the expanding dough into a continuous bar and carries it through the baking step and into the cooling step in the process. The top and bottom belts are grooved so that the side belts fit snugly into them to provide a rectangular confining space.

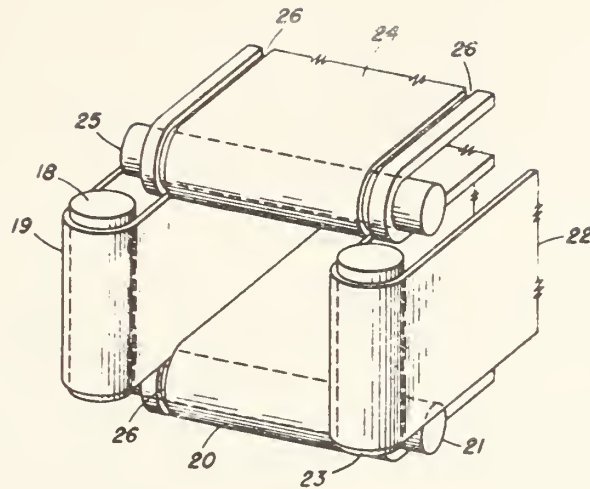


Figure 3. Detail of dough-shaping channel (after J. Booras).

Referring again to fig. 2, the outer section (numeral 12) is a schematic view showing the baking part of the apparatus. At the center is the bar of dough confined by the moving belts. The heat for baking is supplied by dielectric energy from a high frequency alternating field. The electrodes may be built right into the belts confining the dough or may be mounted between their folds. The frequency used is desirably at about 15 megahertz, but may be either higher or lower. According to the patent, a key feature is the porous and heat-conductive nature of the belting. Gases from the baking dough can thus escape, and the hot belt surfaces will cause the surface of the dough bar to brown. Theoretically, then, a fully baked continuous loaf of bread will emerge from the baking channel into the cooling part of the apparatus.

The part of fig. 2 indicated by numerals 16 and 17 shows the portion of the apparatus providing a controlled drop of pressure and ventilation so that much of the heat of the bar can be dissipated by evaporative cooling. Finally the bread bar emerges to be cut into loaf-sized pieces which are then sliced and wrapped in conventional machinery. One published estimate indicates a total of 7 minutes required from mixing to slicing of the bread bar.

Whether or not the process and equipment will operate as proposed, or whether this particular process is ever commercialized, is somewhat beside the point for our purposes today. The significant point is that serious and expert consideration appears already well advanced toward even more revolutionary changes in bread baking than have already been adopted. I can think of other ways to apply the principles just illustrated. I am sure many able scientists and engineers will do so--perhaps already have.

Since I first began to think along these lines, I have had a recurrent mental image of frankfurter sandwiches emerging continuously from a special cooker-extrusion machine with the bun enveloping the sausage being baked in place continuously. The long, continuous hot dog sandwich would need only cutting to desired lengths and packaging in suitable films to be marketed in vending machines or high volume outlets, such as ball games or franchised food purveyors at busy locations.

This mention of vending machines brings up another rapidly growing trend in the food business. I intend here to include vending machines as only a part of the already very large and rapidly growing institutional food market. The demand is high for bakery products of all kinds for preportioned, precooked, prepackaged types of speedy, convenient food service. Many products of the cake and cookie categories are already fairly well suited for this type of service, but more items are needed--especially bread-type products--if wheat food consumption in this country is going to keep up in the face of the terrific and ruthless competition for our food dollar.

I am sure all of you can realize the very great deal of work that remains before any such rudimentary ideas as the continuous hot dog sandwich can be reduced to practice. Several of you are familiar with the pioneer laboratory work and the many years of intensive development work required to make a success of the continuous-mix bread process. Yet, most of the intensive phase could be encompassed in something like 10 to 15 years. Developments of this magnitude can move even faster nowadays.

Another trend you all are aware of will have an influence on the type of product and process development I have just been discussing. This is the emergence of high yielding wheats that Dr. Gilles discussed earlier. I think there is no question that high yield is going to continue to outbalance quality demands as far as the grower is concerned. Also, quality needs may very well differ for each new, high volume, automatic process coming into being. Such quality-demand changes will perhaps pose bigger problems for the miller than anyone else, as quality characteristics of the wheat supply change, but the baker will also be greatly affected. The widest trend in change of wheat quality to date seems to be in the direction of making wheats more nearly similar in quality than is true among older standard varieties or types. I refer here to the short-strawed wheats, in general. It is much too early, of course, to be more than suggestive about this, but the possibility is well worth noting.

If processing cannot fully absorb effects of quality changes, there is danger that wheat will be displaced even more from its traditional uses in baked food products. Wheat flour has already given way to other cereal flours or their fractions in many of the cooker-extruder food products in our markets today. These products are yet mostly snack items, but their vol-

ume is impressive. Also, who is to say that the continuous hot dog I mentioned above might not eventually come out with a crisp, crunchy covering on it, rather than the familiar soft bread-like cover? The crunchy coating, made with no or greatly reduced amounts of wheat flour, might be a little less pleasing to eat, but this might be offset by its convenience, low cost, adaptability to mass marketing and so on. The traditional hot dog thus might eventually be displaced by a modified version having processing requirements more nearly suitable to the automated processing of the future.

This yielding of quality or product integrity to expediency in processing or marketing is a very dangerous thing for agricultural commodities, and several examples are well known. These include the inroads of synthetic fibers into textile products, synthetic rubber, and plastics for building materials. The case of displacement of wheat flour in future baked products or the loss of eating quality in mass produced bakery products is, admittedly, not quite in the same class as these examples. Nevertheless, the danger is similar. Learning enough about wheat flour to permit its manipulation for meeting new processing requirements with no loss of product quality is a high priority goal for research.

In closing this final talk of the final session of this Conference, I want to elaborate a bit more on the concepts of research and development. They are invariably linked, but are really quite different. Research, in my context, is the gathering of new information to serve development. Development will proceed whether or not it is fed by new research information, but development prospers best when guided by information derived from research. Research is, however, a two-edged sword, and results can be very unpredictable. Many times new information will foster displacement of traditional materials, rather than secure or expand their continued use. The topics included in the program of this conference have demonstrated this very well, and I have tried to illustrate this two-way possibility with my example of the continuous hot dog.

A point to remember, however, is that research and development, ideally, must be balanced with one another. Right now, development is proceeding apace, but research is in trouble--not only with us, but all over the world. We need both and we need lots of both. They are needed most when a business or a commodity is in trouble. I would say these are troubled times for wheat.

If any of you have the idea that I might be a partisan for research and development on wheat, you are quite correct. I most certainly am! I want to see wheat restored to a higher place in our economy and diet, and I want us all to be a part of such a restoration. Your all being here with us this week for support of this very goal is very gratifying to us, and we hope that this talk and this session and this program and this conference have fulfilled your expectations in every way.

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